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Essays on growth and migration

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Essays on Growth and Migration

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Universiteit van Tilburg, op gezag van de rector magnificus, prof. dr. Ph. Eijlander, in het openbaar te verdedigen ten overstaan van een door het college voor promoties aangewezen commissie in de aula van de Universiteit op woensdag 16 december 2009 om 16.15 uur door

PIOTR KRZYSZTOF STRYSZOWSKI

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¹This chapter is co-authored by Corrado di Maria (Di Maria and Strykowski, 2009).

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Introduction

This dissertation focuses on two factors that are important for economic growth and per capita income levels of a country. These factors are:

- brain drain, that is migration of high-skilled, trained and talented individuals,
- intellectual property rights (IPR), i.e. legal, exclusive rights to use various types of creations of the mind, such as inventions, names, trademarks, designs *et cætera*.

To better understand the role of these factors in the process of economic development, we construct theoretical models and provide illustrative empirical examples. Below we briefly sketch three studies that constitute the three chapters of this thesis.

Chapters 1 and 2 analyze the effects of brain drain on the economic performance of a country. The migration of highly skilled individuals, was commonly perceived as one of the elements that significantly affected income differences between countries. The empirical impact of brain drain on the destination economies in the long run is observed to be positive (Borjas, 1995). The theoretical studies stressed human capital as the key ingredient in the production and R&D formation, through which the destination country benefits from the brain drain. These studies (e.g. Bhagwati and Hamada, 1974, Kwok and Leyland 1982) highlighted the negative effects of human capital outflow on source economies. However, some sending countries are relatively wealthy compared to their non-sending neighbours (e.g. Taiwan and South Korea compared to Bangladesh and Indonesia). Another striking

example is Canada which despite a relatively high percentage of graduates who migrate to the United States remains one of the wealthiest economies in the world.

In this dissertation, we contribute to the discussion on the origins of the empirically observed ambiguous impact of brain drain on the sending economy by pointing at two transmission mechanisms. We construct theoretical models that capture the complex effects in these transmission mechanism from brain drain on the economic performance of a country. The theoretical analysis is supported by a number of suggestive empirical examples.

In chapter 1, we claim that not all human capital is appropriate for the technology available at a given stage of development of a country. We postulate that the distance to the technological frontier is a key determinant of the appropriateness of human capital: the closer economies are to the frontier, the more they need a balanced work force made up of technical skills, creativity, legal and business expertise. At earlier stages of economic development, when the main task is to copy and apply available technologies, a more intense specialization in technical skills can prove helpful in catching up.

In this chapter, we present a model in which the possibility of migration affects individual educational choices and as a consequence, development of given country. Following Vandebussche et. al (2004), we model economies that can be parameterized by their distance from the technological frontier. Economic growth depends on the amount and composition of the human capital available in the country. The optimal composition depends crucially on the distance from the technological frontier.

Through our model we show that the possibility of migration at early stages of economic development leads to development traps. Facing the prospect of migration, individuals from developing countries decide to acquire inappropriate (from the perspective of a lagging economy) type of human capital. Assuming that migration cannot be (completely) prevented,

countries that take this mechanism into account should subsidize acquisition of technical skills more the further away they are from the technological frontier. These theoretical findings are followed by an empirical illustration of South-East Asian countries that controlled centrally their systems of education and managed to report high rates of economic growth and convergence.

Chapter 2 is motivated by another empirical observation related to the phenomenon of migration: the flows of investments. As shown by numerous empirical studies (e.g. Blomstrom and Kokko, 1997), a technology transfer is one of the consequences of an inflow of foreign direct investment from technologically advanced countries. In what follows, we claim that a brain drain could be beneficial for the sending countries by triggering capital flows from abroad. The theoretical claim about the causal effect of brain drain on capital flows is illustrated by an empirical example. Given the poor availability of data on brain drain, we restrict our empirical analysis to the US-Canada relationship. The consistency and coherence of our data suggests this example to be relevant for the general mechanism. The empirical analysis shows the positive correlation between influx of highly skilled Canadian immigrants to the US and American foreign direct investments in Canada. Moreover, we find that brain drain from Canada to the United States Granger causes the US foreign direct investments into Canada.

The last chapter studies the effects of trade and intellectual property rights on growth rates and income levels. Intellectual property rights play a key role in the modern growth theory, as the majority of the literature (mostly of the so-called Schumpeterian stream) is based on the assumption of infinitely pending patents. The assumption about the patent schemes in the growth literature is rather implicit. Intellectual property rights are assumed to be perfectly enforceable and infinite, that is there is no ideas stealing, patent breaking or

expiry. This assumption is rarely relaxed – usually as “theft” of ideas (Segerstrom, 1991), more rarely as an effect of consistent policy of copying country (Taylor, 1994). As the patents are one of the key fundamentals of the modelling of growth, it is interesting to investigate the effects of endogenous international property rights schemes on economic performance.

The second assumption that was made in the theory of economic growth was the immediate acquisition and free access to every new technology. This was rather dubious as the same studies used to assume that the creation of such technologies was costly and these costs were rising over time (e.g. Young, 1998; Howitt, 1999). The empirical findings tend to support the claim that the diffusion of new technologies is not immediate and the international barriers of technological adoption tend to be significant.

Chapter 3 studies the effects of imperfect international property rights on economic development in the presence of costly technological transfer. We contribute to the existing literature by presenting an advanced theoretical model combining the key features of a Schumpeterian growth model without scale effects² and of a North–South model of trade. We find that strengthening an IPR regime in a country improves its position in the world’s productivity rank, whereas the level of import tariffs tends to be insignificant. This theoretical result we support by an empirical example.

²A model with scale effect predicts that more populous countries grow faster than smaller ones. An absence of clear empirical evidence for this phenomenon has led to construction of growth models without scale effect.

CHAPTER 1

Brain Drain and Distance to Frontier¹

1.1. Introduction

Classical theoretical studies on the *Brain Drain* hold that emigration of highly educated people is beneficial for destination countries and harmful for source ones (e.g. Borjas 1994, Borjas 1995). For immigration countries, the inflow of highly skilled individuals increases the pool of available human capital, and boosts economic growth in the long-run. A specular logic seems to imply that the outflow of ‘brains’ is damaging for the source countries.²

This theoretical prediction, however, is at odds with the experience of some sending countries that grew faster than their relatively more closed neighbours. Examples include Japan, South Korea, Taiwan and Singapore as opposed to Bangladesh, India and Indonesia.³ A recent literature on the effects of the outflow of skilled workers has focused on the potential for a *Beneficial Brain Drain* (BBD), or a *Brain Gain*. The central proposition of studies such as Mountford (1997), Stark, Helmenstein, and Prskawetz (1997) and (1998), Vidal (1998), and Beine, Docquier, and Rapaport (2001) is that, if the possibility of emigration induces more skill-creation than skill-loss, source countries might actually increase their

¹**This chapter is co-authored by Corrado di Maria (Di Maria and Stryszowski, 2009).**

²Several theoretical studies have pointed at the potential negative effect of the outflow of human capital on source countries, among others: Bhagwati and Hamada (1974), Kwok and Leland (1982), Galor and Tsiddon (1997), and Miyagiwa (1991).

³Japan and, to a greater extent, South Korea experienced high levels of skilled emigration in the past decades. South Korea, for example, still had a rate of brain drain of over 9% among highly skilled workers in 1990. In the same year Taiwan and Singapore exhibited even higher rates: 15.2% and 24.8%, respectively. By comparison India (3.9%), Bangladesh (2.1%), and Indonesia (3.9%) suffered a much smaller drain of human capital. These high rates of brain drain notwithstanding, Japan and the Asian Tigers were much more successful in terms of economic performance than the countries in the other group.

stock of human capital, as the possibilities of moving and working abroad increase. One of the simplest mechanisms behind results of this type is that the possibility of emigration might lead economic agents to invest more in their human capital. Yet, since not all of them emigrate in the end, also those who stay in the country of origin have a higher human capital than would otherwise have been the case. Under such circumstances, the simple ‘drain’ effects emphasized by earlier contributions are (possibly) more than compensated by these ‘gain’ effects.

Empirical investigations of the effects of skilled migration on source countries have provided mixed results. While most authors would agree that migration of skilled workers is positive for the destination country,⁴ there is no consensus as refers to the effects on the source economies. Recent empirical work by Beine, Docquier, and Rapaport (2004) has indeed shown that the net effect of the brain drain can be either positive or negative. Despite the significant and positive effect on human capital accumulation that they are able to identify, Beine, Docquier, and Rapaport show that the effects in terms of annual GDP growth are more mixed. Indeed, according to their estimates the BBD hypothesis is supported by the data only for a small number of countries. The authors conclude by noting that "*the simple fact that, among sending countries there are winners and losers, points to the necessity of a better understanding of the circumstances and factors favouring the occurrence of a detrimental brain drain*".⁵ In this chapter we contribute to the debate on the brain drain by focussing on the role played by the *composition* of human capital in fostering productivity growth and, finally, economic development.

⁴See Borjas (1990).

⁵Beine, Docquier, and Rapaport (2004), p.35.

The BBD hypothesis implicitly assumes that the human capital that is accumulated with a view to emigration can prove useful once people remain in their country of origin. One might ask if this is a realistic assumption. Indeed, it runs counter to some empirical evidence showing that countries with similar *levels* but different compositions of education (which we use as a proxy for human capital accumulation) have very different performance in terms of convergence and growth. If all human capital is useful, a higher level should imply faster GDP growth, irrespective of its composition, all else equal.

Although not much addressed in the literature, the different roles played by different types of human capital at different stages of development has been recognized by a number of authors. Both Durlauf and Johnson (1995) and Krueger and Lindahl (2001) provide evidence as to the heterogeneous effects of education on growth across countries with different levels of development. Kalaitzidakis, Mamuneas, Savvides, and Stengos (2001), instead, discuss the existence of non-linearities in the education-growth relationship.

Based on this, in what follows we claim that not all the human capital accumulated with a view to emigration is *appropriate* for the technology available in the source country, and for its level of development. In particular, we postulate that the distance to the technological frontier is a key determinant for understanding the effects of human capital accumulation/composition on economic growth. While the accumulation of human capital seems to imply faster technological advancement and economic growth, we point at the different *types* of human capital that are most useful at different stages of development. This view reflects the idea that technological advances become available either through imitation or through innovation, and that each activity requires (a different combination of) different types of skills. It is reasonable to assume that imitation requires a more technically inclined work force, whereas the more complex activity of innovation requires more than technical

skills alone. Indeed, the closer economies are to the frontier, the more complex their economic and institutional systems, the higher their need for a balanced work force comprising technical skills, creativity, social science competencies, legal and managerial expertise. Conversely, at earlier stages of economic development, when the main task is to copy and adapt available technologies, a more intense specialization in technical skills can prove helpful in catching up.

Following Vandebussche, Aghion and Meghir (2004), we model two economies that can be parameterized by their distance from the technological frontier. Economic development is driven by productivity growth, and productivity improvements depend on the amount and the composition of the human capital available in the country, besides on the distance from the technological frontier. Once at the frontier of technology, productivity advances are only possible through innovation, whereas imitation occurs further away from the frontier. Following our argument above, we assume that imitation is more intensive in technical skills than innovation.

To investigate the distortionary effects of migration on the accumulation of human capital, we model human capital accumulation by agents as an endogenous decision. By letting the type of skills acquired be determined by the costs and benefits faced by heterogeneous agents, we add one important dimension to our model. We are in fact able to investigate the interaction between labour market outcomes, migration possibilities and institutional arrangements, such as the existence of educational policies targeted at satisfying the needs of the local economy.

Our results show the possibility of migration distorts the incentives for agents to accumulate the type of human capital that is appropriate for the country of origin, given its level of development. We show that when migration becomes possible at early stages of economic

development the growth rate of the source economy decreases. We discuss circumstances under which this process leads to development traps, i.e. situations where the process of convergence to the technological frontier stops prematurely. Furthermore, we show that educational policies, in the form of subsidies to particular types of skills, can counteract the negative effects of migration on growth. Assuming that in democratic societies migration cannot be (completely) prevented, our analysis delivers a clear policy recommendation: Countries that wish to maximize their convergence⁶ potential should take this mechanism into account and increasingly subsidize appropriate skills, the further away they are from the technological frontier, and the easier the prospects of migration.

1.2. Education, Migration and Economic Development

At the aggregate level, the relationship between brain drain and economic growth is far from clear. To illustrate this point, we consider the growth rates of the GDP for 128 countries in 2000 and their rate of brain drain – measured as the percentage of tertiary educated residents who emigrate – ten years earlier. Figure 1.1 presents the scatter plot of the two variables and the regression line. The two variables show very little evidence of being correlated, in fact the correlation coefficient, ρ , equals 0.06.⁷

The lack of any significance of this aggregate relationship does not mean much, however, as it simply hides a whole range of situations where countries experienced different degrees of brain drain and various degrees of success in terms of economic growth. Among these, we find the experience of the East Asian economies to be one of the most interesting.

⁶Here, by "convergence" we mean the so-called conditional β -convergence, as introduced by Sala-i-Martin (1996), i.e. the convergence in growth rates, not necessarily income levels.

⁷The regression equation is: $\% \Delta GDP_{2000} = \underset{(6.57)}{3.45} - \underset{(-0.60)}{1.59} \cdot \% Brain Drain_{1990}$. The GDP growth rates are derived from the Penn World Table 6.1 from Heston, Summers, and Aten (2002), the rates of brain drain from Docquier, Lohest, and Marfouk (2005).

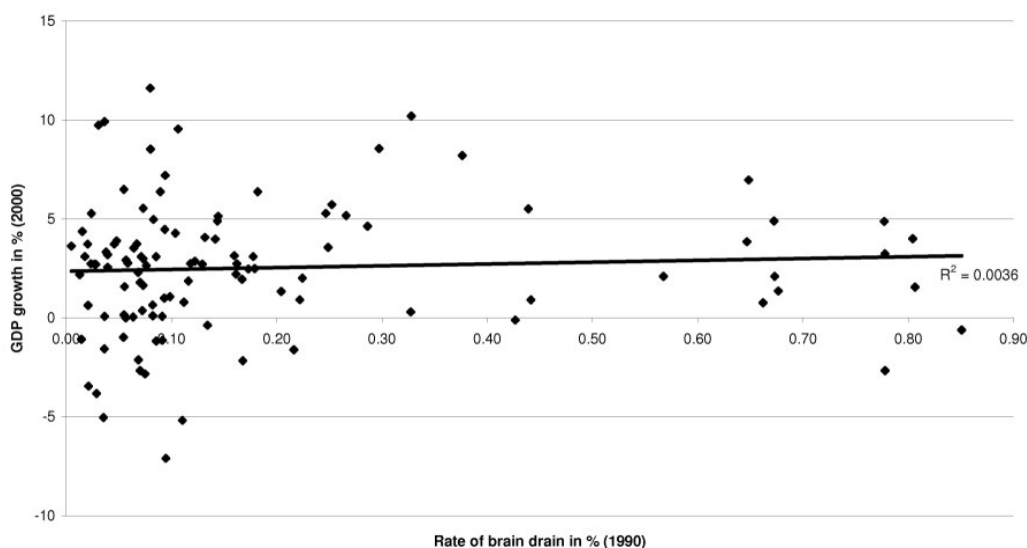


Figure 1.1. *GDP growth and brain drain.*

In the last fifty years countries like Japan, the Republic of Korea, Singapore, Hong Kong and Taiwan all exhibited astonishing growth rates. At the same time, they pursued a policy of open borders, i.e. a significant share of their highly skilled workers left over the years to work abroad. Compared to countries with similar rates of brain drain and initial levels of development, however, these East Asian economies performed much better and managed to catch-up with first-world standards of living (and technological knowledge) within a short time period.

There are many important lessons to be learned from the experience of these countries and, indeed, many pages have been filled with analyses of the East Asian “miracle”.⁸ Here we draw attention to one specific aspect of these economies that has not been fully appreciated by previous analyses: all these economies have exhibited a marked commitment by the government to promote the accumulation of particular types of skills. As World Bank (1993) puts it, “*public funding of post-secondary education focused on technical skills [...] The result*

⁸Two important references analyzing, and rethinking, the East Asian economies’ impressive performance are World Bank (1993) and (2001).

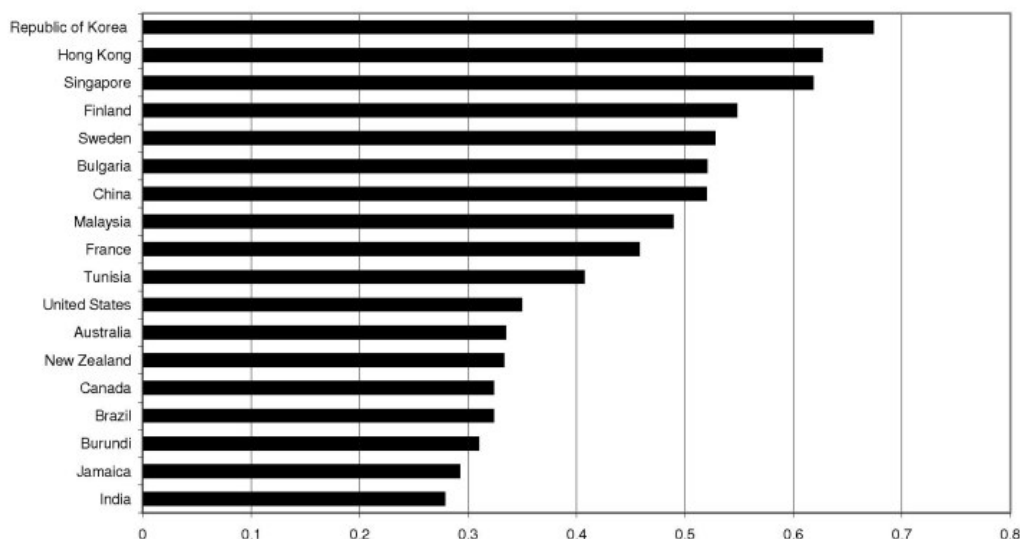


Figure 1.2. *Share of science and engineering students on total tertiary education (1980)*. Source: Own calculations on United Nations Common Data-Base (UNCDB) data.

*of these policies has been a broad, technically inclined human capital base well-suited to rapid economic development”.*⁹

Despite having shares of public expenditure on education in line with, and sometimes lower than those in other developing countries,¹⁰ the East Asian economies chose to support the accumulation of specific types of skills which were deemed most useful to economic development. As shown by the graph in Figure 1.2, there is no clear relationship between the accumulation of ‘technical’ skills and the level of economic development. The Figure reports the percentage of science and engineering students in the total, in 1980, for an indicative cross-section of developed and developing countries.¹¹ One remarkable feature of these data

⁹Ibid., page 15. Emphasis added.

¹⁰In 1960, for example, the Republic of Korea spent 2.0% of its GDP on education, in the same year Brazil’s share was 1.9%, and the average for Sub-Saharan African countries was 2.4%. In 1989, Korea’s budget for education increased to 3.6%, Brazil’s reached 3.7% and for the same sub-set of African countries the share topped 4.1%. These figures are taken from World Bank (1993), table 5.3.

¹¹Figure 1.2 is based on computations by the authors on UNCDB data.

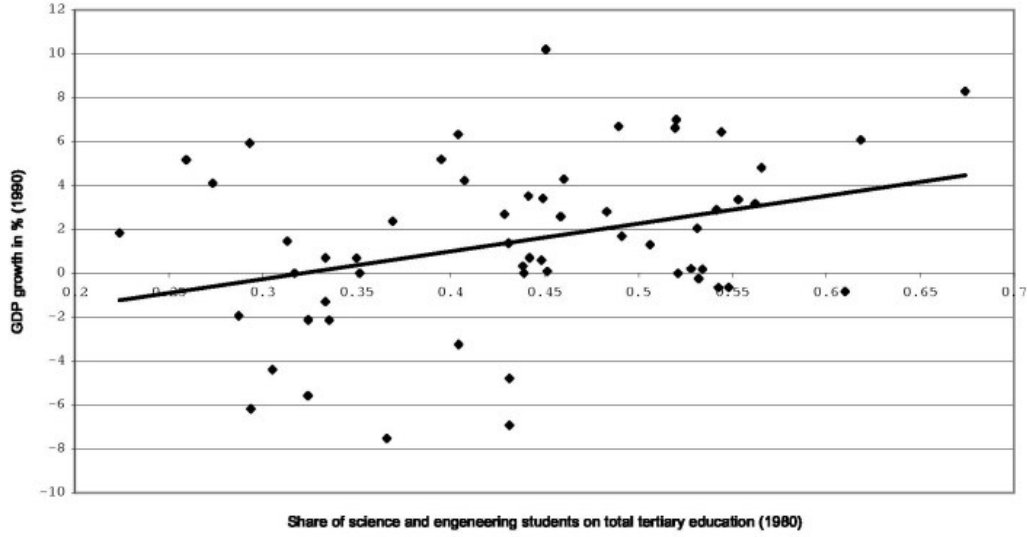


Figure 1.3. *GDP growth (1990) and the share of S&E students (1980).*

is that both poor and rich countries exhibit either high or low shares of technical students (China vs. India or Finland and Sweden vs. New Zealand and Canada, for example), so that no clear pattern is visible. What is apparent, instead, is that countries like the Republic of Korea, Hong Kong and Singapore are at the top of the distribution.

Can this high share of technically skilled workers explain, at least in part, the success of the East Asian economies? Another simple graph lends support to this claim. Figure 1.3 plots the growth rate of a number of developed and developing countries in 1990, against the share of science and engineering students on total tertiary education in 1980 and the corresponding regression line.¹² The plot implies that having a higher share of science and technology students could be on average an advantage in terms of growth performance.

The other interesting aspect is how such a composition of human capital was obtained. Most East Asian economies, in fact, represent clear examples of the government's intervention

¹²The equation representing the line is: $\% \Delta GDP1990 = -4.13 + 10.97 \cdot \%S\&E1980$; the sample consists of 53 countries. Data derived from the Penn World Table 6.1 and the UNCDB.

into the structure of the tertiary education. In Japan, for example, the system comprising the National Institute for Educational Policy Research (NIER), founded in 1949, and the Ministry of Education, Sports and Culture,¹³ has for a long time been perceived as the “Super-ministry” responsible for adjusting the structure of Japanese schooling to the needs of local industries. Similar institutional structures also exist in the countries of the group of the so-called “Asian Tigers”.

More recently, however, there has been an increasing effort to move away from the predominance of the government and towards the utilization of market mechanisms, especially in Japan where a deep reform of the educational system is currently under way. Analysts have argued that such moves reflect fundamental shifts in the mode and direction of social development. To quote a recent OECD report: “*the increased diversity and complexity of the modern society and its needs, necessarily have made centralized decision and control obsolete [...] [M]arket mechanisms will be the only way to achieve diversified and multidimensional changes*”.¹⁴

This shift in paradigm is consistent with the main ideas of our proposed framework. Since the advancement of knowledge, which is at the basis of economic growth, can either occur through the creation of new technologies (ideas) or through the adoption of old technologies from abroad, and since these two activities require different compositions of human capital, the optimal structure of human capital depends crucially on the stage of development of any given economy. Thus, in the presence of distortions, different types of public policies can be

¹³In January 2001, the former Ministry of Education, Sports and Culture and the former Science and Technology Agency were merged and the new Ministry of Education, Culture, Sports, Science and Technology was founded.

¹⁴This quote is from the Japanese National Report of the OECD IMHE-HEFCE project on international comparative higher education financial management and governance, 2004.

necessary to favour the accumulation of different types of human capital at different stage of development.

We focus on the possibility of migration as one such potential distortion. By blurring the borders between economic systems at different levels of economic development, migration distorts the incentives for the optimal accumulation of human capital: agents in lagging countries prefer to acquire the type of human capital that would be more profitable in case of successful migration. Thus the distance to frontier in different countries could offer a useful key to understanding the effects of the brain drain on economies at different stages of development.

Moreover, policy could provide a way to offset this harmful effect of brain drain on human capital composition, by regulating the structure of education, as we will argue in what follows.

1.3. The model

We describe an economy consisting of two countries, one large destination country and one small source one. We assume that the destination country (which we can think of as the group of the OECD countries for concreteness) is the technological leader, whereas the source country is technologically less developed.¹⁵ The economies are populated by workers and firms.

Workers accumulate skills, and supply skilled labour to firms. Skill accumulation is costly in that some time is necessary to acquire knowledge. We assume that workers differ in their abilities (their ‘talent’), so that certain types of skills are more difficult to accumulate (i.e. more time is required) for some agents than for others. For simplicity, we assume that all

¹⁵In what follows we use the terms *destination country*, *technological leader*, and *leading country* interchangeably. The same goes for *source country*, *technological follower*, and *lagging country*.

workers accumulate skills and that it is only possible to acquire two types of skills which we broadly label ‘technical’ and ‘general’. Consequently, in the model there are two types of workers: technically-skilled (T) and generally-skilled (G) ones.

Since the net rewards to the accumulation of different skills depends on the wage commanded by the specific skill and the cost it entails (in terms of foregone earnings), each worker decides on the type of skills she wants to acquire based on her specific type.

Each firm engages in production of an intermediate, needed in the production of the final good, and invests in technology improvements. We assume that workers are only used in the latter activity. Hence, firms decide how many workers of each type to employ in the ‘research’ sector, given that technology can be improved either through R&D activities (innovation proper), or by adopting existing technologies from the world technological frontier (imitation).

In the next subsections we describe in greater details the accumulation decisions made by workers and the parallel innovation choices facing firms. We discuss the choices in a situation of autarchy, that is a situation in which no migration possibility exists. This discussion fully characterizes the destination country, given our assumption that it is large enough so that smaller foreign markets are not relevant to its agents’ decisions. Notice, moreover, that throughout the chapter we ignore the possibility that goods are traded; we do this to be able to clearly identify the effect of migration on workers’ accumulation decisions. Hence, the alternative to autarchy in our framework is simply a situation in which workers are allowed (with some positive probability) to move from the lagging to the leading country.

1.3.1. Investment in education

Each period new cohorts of workers of fixed size are born in each country, thus there is no population growth. We assume that the population size in the leading country, \bar{L} , is larger than L , the population in the lagging country. We further assume that the number of firms per capita is the same in both economies. This has two consequences: first, the number of firms is larger in the leading rather than in the lagging country; second, the number of workers per firm will be the same across countries. In this fashion, the relative size of the two economies plays no role in the model. Without loss of generality, as long as we only look at one country at the time, we can simplify the analysis by letting the population size equal 1.

Workers only live for one period: each period new agents are born, they decide about their education, they work for a wage, consume all their income and finally die.

Workers are risk neutral and differ only with respect to the cost they have to incur to accumulate different types of human capital. They are indexed by j according to their talent and uniformly distributed over the interval $[0, 1]$, with the convention that $j = 1$ corresponds to the most talented individual. The talent of an agent determines her relative cost of acquiring general skills. Agent j needs to spend a fraction $1 - j$ of her time to acquire these skills, while we assume that the time-cost of acquiring technical skills is independent of talent and equal to $1 - \xi$ for all workers, where $\xi \in (0, 1)$. Agent j will thus be able to offer j units of general skills, or ξ of technical skills. Our modelling choices don't make general skills overly costly for any individual, however, for some of them technical skills are easier to acquire and they will therefore invest in that direction.

The composition of skills between technical and general ones will be determined by the relative costs of skills accumulation, and by the relative rewards to the particular kind of skills. Letting the salary for a G -skilled worker at time t be $w_{Gt} = \omega_{Gt} A_{t-1}$ – where ω_{Gt} is the wage per effective unit of human capital provided at time t , and A_{t-1} indicates the level of total factor productivity at time $t - 1$ – and the salary for a T -skilled individual be $w_{Tt} = \omega_{Tt} A_{t-1}$, it is possible to identify the marginal worker, j' . Agent j' , the worker who is indifferent between acquiring technical skills (and earning ω_T per each unit she provides) and general ones (thereby earning ω_G per unit), must satisfy the following condition:

$$(1.1) \quad \omega_{Tt} \xi = \omega_{Gt} j'.$$

All agents indexed by $j \in [0, j']$, will accumulate technical skills, conversely, agents with $j \in (j', 1]$ will choose to become generalists. Accordingly, the total supply of G -skilled labour equals,¹⁶

$$G_t = \int_{j'}^1 j \, dj = \frac{1}{2} (1 - j'^2);$$

which can be easily solved for j' , yielding:

$$(1.2) \quad j' = \sqrt{1 - 2G_t}.$$

Rearranging equation (1.1) and using the above expression to substitute for j' , we get the following expression for the relative wages as a function of the supply of G -skilled labour:

$$(1.3) \quad \omega \equiv \frac{\omega_{Gt}}{\omega_{Tt}} = \frac{\xi}{\sqrt{1 - 2G_t}}.$$

¹⁶Notice that this specification implies $G \leq 1/2$.

Finally, note that the constraint that $j \in [0, 1]$ implies that the supply of graduates with technical background depends on the supply of G -skills. Hence, the supply of T -skilled labour is given by:

$$(1.4) \quad T_t = \xi j' = \xi \sqrt{1 - 2 G_t}.$$

1.3.2. Production and technological progress

In the leading country there are \bar{N} firms, while in the lagging country there are only $N < \bar{N}$ of them. As discussed above, the number of firms in each country is proportional to the number of workers in each country, so that the size of the economy is immaterial. Thus, for the sake of generality, we indicate the number of firms by ν in what follows. Each firm produces one intermediate input for the production of final output, and engages in productivity-enhancing activities employing skilled workers.

Final output is produced competitively using a continuum of mass ν of intermediates, accordingly to the following production function:

$$(1.5) \quad Y_t = \int_0^\nu A_t^{1-\alpha} x_{i,t}^\alpha di,$$

where $\alpha \in (0, 1)$ and $x_{i,t}$ is the amount of intermediate good i used to produce Y at time t . Given that the final product is produced competitively, the price of intermediate input i equals to its marginal product, i.e.:

$$\alpha A_t^{1-\alpha} x_{i,t}^{\alpha-1}$$

Each intermediate producer acts as a (local) monopolist and produces good i using the final good with a one-to-one technology. It is then easy to show that, for a given level of A_t , the equilibrium demand for input i equals $x_{i,t} = \alpha^{\frac{2}{1-\alpha}} A_t$. Hence, profit maximization on the part of intermediate goods' producers implies that for each firm monopoly profits equal:

$$(1.6) \quad \pi_t = \zeta A_t,$$

where $\zeta \equiv \frac{1-\alpha}{\alpha} \alpha^{\frac{2}{1-\alpha}}$.

Thus, firms maximize their profits by maximizing their productivity level. Moreover, using the expression for inputs' demand derived above, it is straightforward that the level of final output is linear in the level of technology and, as a consequence, the growth rate of output will be the same as the growth rate of technology. Keeping this in mind, we now analyze the choice faced by firms in formulating their technological development plans.

Firms employ skilled workers to increase productivity. We assume that productivity can be improved by directly involving in R&D activity or by adopting existing technologies from the world technological frontier:¹⁷

$$(1.7) \quad A_t = A_{t-1} + A_{t-1} T_{nt}^{\phi} G_{nt}^{1-\phi} + (\bar{A}_{t-1} - A_{t-1}) T_{mt}^{\sigma} G_{mt}^{1-\sigma}.$$

Here T_{nt} represents the amount of T -skills used in innovation at time t , while T_{mt} refers to the amount in imitation. The same applies to G_{nt} and G_{mt} . We assume that both types of skills are needed in both innovation and imitation, and that the two activities differ in that

¹⁷This modelling choice closely follows Vandenbussche, Aghion and Meghir (2004), who, in turn, derive it from Benhabib and Spiegel (1994) and Acemoglu, Aghion and Zilibotti (2006).

the productivity of G -skilled workers is higher in innovation than in imitation, i.e. we let $\sigma > \phi$.

Furthermore, the technological improvement function in (1.7) implies that imitation is more productive the further away a country is from the technological frontier, \bar{A} . This is intuitive since a larger technological gap means that more innovations can be usefully adopted from abroad. Innovation, instead, becomes more productive with the own technology level, A , formalizing the idea that a broader technological base is needed to push the frontier further.

1.4. Equilibrium under autarchy

To characterize equilibrium situations under autarchy, we need to discuss three possible types of equilibrium according to the regime of technological change that takes place. In what follows, we distinguish between equilibria that occur under innovation, equilibria that obtain under imitation, and mixed equilibria where both activities take place at the same time.

Let us start with the case where innovation is the only type of productivity-enhancing activity performed in equilibrium. In this case, new technologies develop according to:¹⁸

$$(1.8) \quad \bar{A}_t = \bar{A}_{t-1} + \bar{A}_{t-1} \bar{T}_t^\phi \bar{G}_t^{1-\phi}.$$

¹⁸From now on, we identify variables that refer to the innovation-only case by an upper bar. Variables without the upper bar refer the imitation-only equilibrium. When necessary, we will distinguish the mixed equilibrium variables with a tilde: \sim .

Profit-maximizing firms will choose the amount of each type of skilled labour to employ in innovation, in order to solve the following maximization problem:

$$(1.9) \quad \max_{\bar{G}_t, \bar{T}_t} \pi_t = \zeta \bar{A}_t - \bar{\omega}_{Tt} \bar{A}_{t-1} \bar{T}_t - \bar{\omega}_{Gt} \bar{A}_{t-1} \bar{G}_t,$$

subject to (1.8).

The first-order conditions for this problem are,

$$(1.10) \quad \bar{\omega}_{Gt} \equiv \frac{\bar{w}_{Gt}}{\bar{A}_{t-1}} = (1 - \phi) \zeta \left(\frac{\bar{T}_t}{\bar{G}_t} \right)^\phi, \text{ and}$$

$$(1.11) \quad \bar{\omega}_{Tt} \equiv \frac{\bar{w}_{Tt}}{\bar{A}_{t-1}} = \phi \zeta \left(\frac{\bar{T}_t}{\bar{G}_t} \right)^{\phi-1}.$$

The above equations, together with (1.3) constitute the equilibrium. Taking the ratio of (1.10) and (1.11) and substituting for \bar{T} from the expression in (1.4), one gets the following expression for the demand of G -skilled labour:

$$(1.12) \quad \bar{\omega}_t \equiv \frac{\bar{\omega}_{Gt}}{\bar{\omega}_{Tt}} = \frac{1 - \phi}{\phi} \frac{\sqrt{1 - 2\bar{G}_t}}{\bar{G}_t}.$$

Using this and the supply function in (1.3), we can illustrate the equilibrium graphically in the (ω, G_t) plane (see Figure 1.4, where $\omega \equiv \bar{\omega}_{Gt}/\bar{\omega}_{Tt}$). The demand for generalists is represented with the downward sloping curve \bar{D} , whereas the supply is represented by the upward sloping curve S . The equilibrium obtains when both conditions are satisfied simultaneously, that is at a point like $(\bar{\omega}^*, \bar{G}^*)$. This point represents the equilibrium when a country is fully specializing in innovation, thus this is the equilibrium prevailing the destination country.

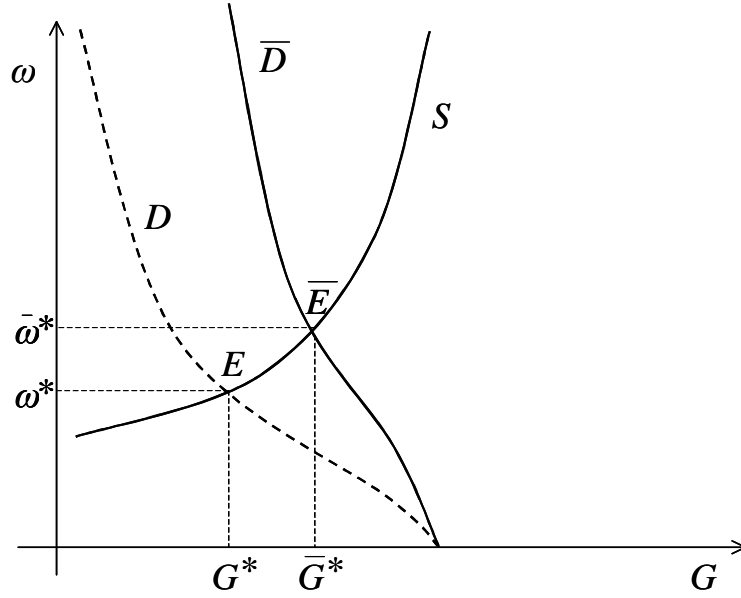


Figure 1.4. *The equilibrium without migration in the two countries.*

Analytically, it is straightforward to solve for the equilibrium level using 1.3 and 1.12, to get:

$$\bar{G}^* = \frac{1}{\xi\Phi + 2}, \text{ and } \bar{\omega}^* = \xi \sqrt{\frac{\xi\Phi + 2}{\xi\Phi}},$$

where we have used $\Phi \equiv \frac{\phi}{1-\phi}$.

At the other extreme, we focus on the case in which a country only resorts to imitation to increase their technological level. Local firms, thus fully specialize in imitation. Except for this, they behave exactly like their counterparts in the previous case: amending the relevant production function, they choose G_t and T_t to maximize their profits,

$$(1.13) \quad \max_{G_t, T_t} \pi_t = \zeta [A_{t-1} + (\bar{A}_{t-1} - A_{t-1})T_t^\sigma G_t^{1-\sigma}] - \omega_{Tt}A_{t-1}T_t - \omega_{Gt}A_{t-1}G_t.$$

Hence, their demand for G -skilled labour equals:

$$\omega_t = \left(\frac{1-\sigma}{\sigma} \right) \frac{\sqrt{1-2G_t}}{G_t}.$$

Since $\sigma > \phi$, the demand curve for the case of imitation (the dashed line D in Figure 1.4) lies below the demand curve for innovation. Intuitively, it is clear that, since skills of type G are more productive in innovation than in imitation, for any given relative wage firms specializing in innovation would demand relatively more G skills than firms specializing in imitation. Just as before, the equality of demand and supply will determine the equilibrium levels of the relative wage and of the supply of G -skills:

$$G^* = \frac{1}{\xi\Sigma + 2}, \text{ and } \omega^* = \xi \sqrt{\frac{\xi\Sigma + 2}{\xi\Sigma}},$$

where $\Sigma \equiv \frac{\sigma}{1-\sigma}$.

From $\sigma > \phi$, we conclude that when countries fully specialize, the country that does so in innovation will have a higher level of G .

To complete our analysis, we need to address what happens when firms don't fully specialize in either activity. In this case, they will adopt the combination of the two activities which allow them to maximize their profits. In terms of Figure 1.4, equilibria of this type will correspond to points along the supply curve S , comprised between E and \bar{E} . The weight of each type of activity, innovation and imitation, will be determined by the relative productivity of each. The higher is the weight of imitation, the closer the mixed equilibrium will be to E , and *vice versa* for innovation.

As mentioned at the end of the previous section, the productivity of imitation is higher, the wider the technological gap. Innovation, on the other hand, is more productive the closer a country is to the technological frontier. Thus, at an intuitive level it seems reasonable that, as we move up along the technological ladder, we encounter countries progressively more active in innovation. In terms of Figure 1.4, this implies that the equilibrium would

gradually shift from point E , where only imitation occurs, to point \bar{E} , where innovation is the only activity taking place.

Given the structure of 1.7, countries that have a low level of technology have larger incentives – represented by the term $(\bar{A}_t - A_t)$ – to engage in imitation. These incentives, however, decrease with the reduction of the distance to frontier. Thus, it would seem that imitation occurs far away from the frontier; imitation and innovation coexist as the distance to frontier gets smaller; while only innovation takes place for low levels of the technological gap. Indeed, in the proposition that follows we show that the choice of the type of activity to undertake only depends on the distance-to-frontier parameter, that we define as $a_t = \bar{A}_t/A_t \geq 1$.

Proposition 1.1. *Consider the economy described above. There exist two critical values of the distance to frontier – \tilde{a}_l and \tilde{a}_h – such that, when $a_{t-1} < \tilde{a}_l$ only innovation occurs in the equilibrium; when $a_{t-1} > \tilde{a}_h$ only imitation occurs in the equilibrium; and when $a_{t-1} \in (\tilde{a}_l, \tilde{a}_h)$ both activities take place in the equilibrium.*

Proof. See the Appendix at the end of this chapter for the proof, and for the expressions of \tilde{a}_l and \tilde{a}_h . □

According to this proposition, there are values of the distance-to-frontier for which both innovation and imitation occur simultaneously: this is indeed the case when a_{t-1} lies between \tilde{a}_l and \tilde{a}_h , as defined in the Appendix. In this case, the equilibrium is characterized by a value of the wage that depends on a_{t-1} , $\tilde{\omega}(a_{t-1})$, defined as

$$(1.14) \quad \tilde{\omega}(a_{t-1}) \equiv \left[(a_{t-1} - 1) \frac{1 - \sigma}{1 - \phi} \left(\frac{\sigma}{1 - \sigma} \right)^\sigma \left(\frac{1 - \phi}{\phi} \right)^\phi \right]^{\frac{1}{\phi - \sigma}},$$

and such that $\tilde{\omega}(a_{t-1}) \in [\omega^*, \bar{\omega}^*]$. The corresponding level of the total supply of skills, $\tilde{G}(a_{t-1})$ say, can be read on the labour supply curve, S in Figure 1.4.

Hence, our economies have an equilibrium at (ω^*, G^*) for all levels of $a_{t-1} \in [\tilde{a}_h, +\infty)$, in which case full-specialization in imitation will obtain; the equilibrium switches to a non-specialization regime with both imitation and innovation happening at the same time, and $(\tilde{\omega}(a_{t-1}), \tilde{G}(a_{t-1}))$ for intermediate levels of a i.e. for $a_{t-1} \in (\tilde{a}_l, \tilde{a}_h)$; finally, full specialization in innovation will occur when $a_{t-1} = \tilde{a}_l$. In this last case, the wage rate and the equilibrium level of G -skills are $\bar{\omega}^*$ and \bar{G}^* , respectively.

Before moving on to considering how the distance to frontier of the lagging country evolves over time, there is another important point to make. Since the labor market is competitive, the wages equal marginal products, hence there are no extra profits from innovation. However the monopoly profits in the market for intermediates depend on the productivity level. In the absence of any external distortions, thus, the technological level is maximized. Since the growth rate of technology is given by $g_t = (A_t - A_{t-1})/A_{t-1}$, and A_{t-1} is predetermined, the maximization of technology improvements results in output growth maximization at each point in time. In other terms, in the absence of any other distortions, the market mechanisms are enough to generate the appropriate incentives for firms and workers to allocate resources optimally (in terms of growth). We close this section with the following result:

Proposition 1.2. *In the absence of migration, the market solution is growth maximizing.*

Proof. See the Appendix at the end of this chapter . □

1.5. Convergence under autarchy

Having described the possible equilibria, in this section we analyze the evolution over time of the distance to frontier in the source country when no migration is possible. We

show that the lagging country tends to grow faster than the leading one, and converges over time towards the technological frontier. Recall that the distance to frontier at time t is defined as:

$$a_t = \frac{\bar{A}_t}{A_t} \geq 1,$$

thus, as long as the growth rate of the lagging country is larger than the growth rate of the leading one, convergence towards the frontier will occur, that is a_t will decrease over time.

Under autarchy, both the leading and the lagging country enjoy a growth maximizing allocation of workers across skills, that is the ratio T_t/G_t that arises in equilibrium, maximizes the growth rate as shown above in Proposition 2.

The growth rate for the leading country, \bar{g} , is given, from 1.8, by

$$\bar{g} = \frac{\bar{A}_t - \bar{A}_{t-1}}{\bar{A}_{t-1}} = \bar{T}_t^\phi \bar{G}_t^{1-\phi},$$

and it only depends on the equilibrium levels of \bar{T}_t and \bar{G}_t , which are independent of a_t and constant over time.

To determine the evolution over time of the distance to frontier of the lagging economy, we need to compare its growth rate with the growth rate of the frontier country, \bar{g} . Consider first what happens when the source country is very far from the frontier and, in particular, when its distance to frontier, a_t , is larger than the critical value \tilde{a}_h . Under these circumstances, the lagging country fully specializes in imitation and its growth rate is given by $(a_{t-1} - 1)T_t^\sigma G_t^{1-\sigma}$. Contrary to what happened in the leading country, in this case the growth rate increases with the distance to the technological frontier, as imitation is more productive the larger the technological gap. The lagging country thus grows faster than the technological leader and gets closer (at decreasing rates) to the frontier.

When the distance to frontier reaches the threshold \tilde{a}_h , firms in the lagging country also begin innovating, as it now proves profitable for them to do so.¹⁹ By combining the two activities firms maximize their productivity, and the growth rate of the lagging economy remains higher than the rate of expansion of the frontier (\bar{g}). The process of convergence continues until the distance to frontier reaches the level at which companies in the lagging country fully switch to innovation, i.e. until $a_{t-1} = \tilde{a}_l$. Once the lagging country has reached this threshold, it makes use of the same production function as the leading country to increase productivity: the growth rates of the two countries are now equal, and the process of convergence is completed. These is summarized by the following:

Proposition 1.3. *In the absence of migration, the lagging country achieves convergence, and reaches the steady-state distance to frontier \tilde{a}_l .*

Proof. See the Appendix at the end of this chapter . □

The intuition behind this result is relatively straightforward: recall that firms always choose the composition of innovation/imitation that maximizes the rate of productivity growth. Indeed, we know from Proposition 1.2 that in the absence of migration the market outcome is growth maximizing. When a country is lagging away from the frontier, i.e. when the distance-to-frontier parameter a_{t-1} is larger than \tilde{a}_l , it is advantageous for firms to perform at least some imitation and not to fully specialize in innovation: firms exploit the higher productivity of imitation (away from the frontier) relative to innovation, for any given level of the relative supply of skills. Thus, as long as there is some gains to be earned by imitating, the average productivity (and hence the growth rate) will be higher for the

¹⁹As discussed in the proof of Proposition 1 in the Appendix at the end of this chapter, the value of \tilde{a}_h and \tilde{a}_l only depend on the values of the production elasticities, and on the equilibrium levels of ω_G and ω_T , that are both independent of a_{t-1} .

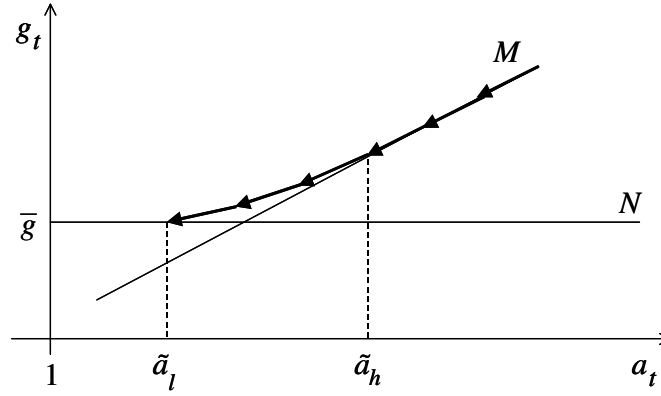


Figure 1.5. *Convergence under autarky.*

lagging country than for the leading country. At any distance from the frontier larger than \tilde{a}_l , the lagging country has a growth rate higher than \bar{g} and the technological distance that separates it from the frontier tends to decrease.

This catching-up effect, reminiscent of similar effects in the technology diffusion literature (see, e.g. Barro and Sala-i-Martin, 1995), vanishes when the technological gap disappears. When there are no longer advantages to be derived from imitation, innovation is the only means to foster productivity; full specialization occurs (see Proposition 1.1), and convergence to the group of technological leaders has been accomplished.

Graphically, this is presented on the (a_t, g_t) plane in Figure 1.5. The horizontal dashed line N , stands for the growth rate of the innovating, frontier country, \bar{g} . The upward-sloping line M describes the growth rate reported by the economy that employs technological adoption as its only means to increase productivity. This line slopes upwards because of the increasing benefits of lagging behind the frontier, as discussed above. The solid line with arrow represents the lagging economy's process of convergence towards the frontier, through

the three different phases of imitation-only (the straight part of the solid line), imitation-innovation (the curved part) and innovation-only, when it reaches the distance $a_t = \tilde{a}_l$, where convergence is complete.

1.6. Migration and distance to frontier

We now turn to analyzing the effects of the possibility of migration on the growth rate of the lagging country, and on its steady-state level of income.

Assume that both G -skilled and T -skilled workers in the lagging country have some non-negative, exogenous probability, p_G and p_T respectively, to migrate to the more developed leading country. We assume that migration is random, i.e. there is no possibility of screening potential migrants, and hence workers of each type face the same probability of migration. First, we study the case when the probability of migration is the same for both types of workers. Next, we analyze what happens when one type is favoured by the destination country, i.e. when agents of a given type have a higher probability of migrating.

1.6.1. Uniform probability of migration

Suppose that both types of skilled agents G and T have the same chances to migrate to the frontier country: i.e. having acquired their skills, workers will be able to offer their labour services abroad with probability $p_G = p_T = p \in (0, 1)$.

The possibility of migration influences the accumulation decisions of workers only in the source country. Indeed, since wages in the lagging country are lower than in the leading one, migration proves unappealing to skilled workers from the leading country. In the lagging country, however, rational workers will take into account that with some probability they will be able to migrate to the more advanced country and obtain higher wages.

In this context, the condition for the marginal worker in the destination country reads:

$$(1.15) \quad (p a_{t-1} \bar{\omega}_{Tt} + (1-p)\omega_{Tt}) \xi = (p a_{t-1} \bar{\omega}_{Gt} + (1-p)\omega_{Gt}) j'.$$

Recalling the expression used in 1.2 to identify the indifferent worker,

$$j' = \sqrt{1 - 2G_t},$$

we immediately see that (1.15) implicitly expresses the supply of G -skilled labour in the source country, for any level of p and a_{t-1} . In a graph similar to the one in Figure 1.4, the supply curve under migration is characterized by a lower level of ω than the original curve S , for each level of G . Indeed, for workers to supply any level of G -skills (smaller than \bar{G}^*) the domestic relative wage has to be lower than before, given that the relative wage abroad is never lower than at home. Figure 1.6 presents the relative graph. Notice that in the specific case where the migration probability is the same for both types of workers, the two lines coincide when both countries specialize in innovation (at point \bar{E} in the Figure).²⁰

Firms' decisions to hire workers only depend on domestic conditions: given our assumption that the share of entrepreneurs is the same in the two countries, the number of workers per firm is the same in the two countries and across regimes. Thus, the possibility of migration does not affect the firms' decision in any way: firms still maximize profits taking the wage level as given.

²⁰From equation 1.15, it is possible to rewrite the supply of G -skills in terms of ω as $\omega = \omega_{\text{no-}\mu} - (\bar{\omega} - \omega_{\text{no-}\mu}) \frac{pa\bar{\omega}_T/\omega_T}{1-p}$, where $\omega_{\text{no-}\mu} = \frac{\xi}{\sqrt{1-2G}}$ expresses the wage under autarchy, for each level of G . Since $\bar{\omega}$ is the maximum value for the equilibrium level of the relative wage, it follows that indeed, in the (G, ω) plane, the supply of G -skills under migration is below S for $a > \tilde{a}_l$, or, which is equivalent, for $G < \bar{G}^*$.

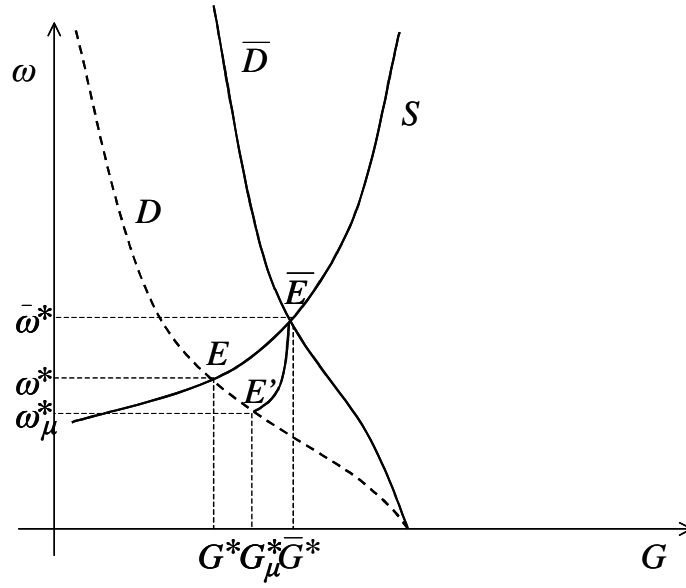


Figure 1.6. *Demand and Supply under Migration.*

As before, labour demand and labour supply jointly determine the equilibrium level of G and T . The probability of migration influences these equilibrium levels by distorting the accumulation incentives of the workers.

To understand why, remember that while workers respond to price incentives from both countries, firms only face domestic prices. Thus, at every equilibrium there will be a wedge between the wage ratio perceived by workers and the wages faced by firms. With the exception of point \bar{E} where countries are *de facto* identical as refers to wage rates and technology, at every other migration equilibrium workers will perceive higher wage rates than firms. In particular the wage rate ω perceived by workers will be higher than the one perceived by domestic firms. This is due to the fact that the alternative to working at home is to work abroad, where only innovation takes place: since generalists are more productive than technicians in innovation, they are relatively more rewarded in the leading economy. Thus, workers naturally bias their decision towards G -skilled labour. From Figure 1.6, it is apparent that, with the exception of point \bar{E} , where only innovation occurs, every equilibrium point under

migration will be characterized by a higher level of G -skills than the corresponding autarchy equilibrium. As this happens, the economy moves away from the growth-maximizing factor composition, T^*/G^* (see Proposition 1.2), at each level of the distance to frontier larger than \tilde{a}_l . Hence, the growth rate of the source economy declines, leading to the following result:

Proposition 1.4. *When migration of skilled workers is possible, the growth rate of the lagging economy is reduced for all $a \in (\tilde{a}_l, \infty)$*

Proof. In text. □

As before, however, when the distance to frontier is \tilde{a}_l , firms still specialize in innovation at point N ; offer a relative wage equal to $\bar{\omega}^*$; and hire \bar{G}^* workers. Indeed, when the probability to migrate is the same for both types of workers, the distortionary effect of migration decreases with the level of specialization in innovation, or which is the same, it increases with the distance to frontier (see equation 1.15). When the lagging country fully specializes in innovation, the possibility of migration ceases to play any role. In this situation the education incentives for agents are identical in both countries.

Elsewhere, however, things are more complicated. For firms it will still be profitable to combine innovation and imitation for any level of the distance to frontier larger than \tilde{a}_l . The range (in terms of a) where the two activities coexist, however, is larger now than under autarchy. The supply of G -skills is in fact larger along the $E' - \bar{E}$ line than along the S line, for any ω . As a consequence, at \tilde{a}_h the level of G (and of T) will differ from its optimal level G^* . Hence, imitation only is not productive enough at \tilde{a}_h to justify full specialization in this activity. Specialization will necessarily occur at a level of a larger than \tilde{a}_h , call it \tilde{a}_{h1} , given that the productivity of imitation increases with the distance to frontier. This discussion leads us to our next result:

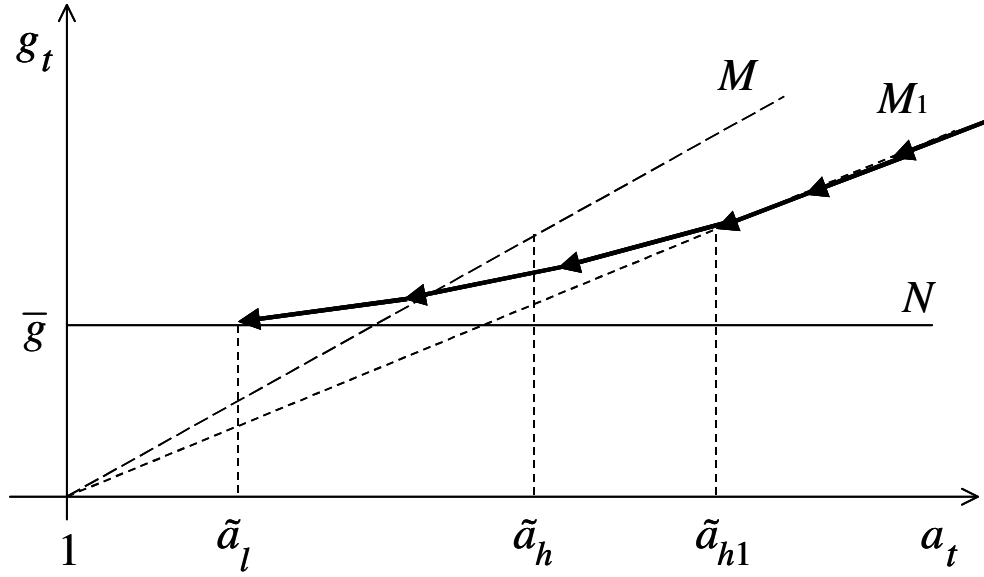


Figure 1.7. *Convergence with migration, and $p_G = p_T$.*

Proposition 1.5. *When migration of skilled workers is possible, and $p_G = p_T = p$, the lagging country converges at a steady-state distance to frontier equal to \tilde{a}_l .*

Proof. See the Appendix at the end of this chapter. □

The conclusion from this and from Proposition 4 is that when no type of skill is favoured by the leading country in terms of migration, the lagging country still converges to the same level of development as before the introduction of migration, but it does so at a slower rate than before.

We can summarize the effects of the probability of migration in this situation as follows: in the first place migration distorts the accumulation of human capital reducing the growth rate (from imitation). Graphically, this is presented in Figure 1.7, where the downward sloping line M_1 is below the line M , that represents the growth rate without migration. Second, since imitation is now less productive *cæteris paribus*, firms will tend to begin innovating further away from the technological frontier. Indeed, the threshold value for innovation, \tilde{a}_h ,

shifts right to \tilde{a}_{h1} in Figure 1.7.²¹ Third, the process of convergence, however, continues up to the point \tilde{a}_l , the same one as in the no-migration case, since the distortionary effect of migration is irrelevant when both countries specialize in innovation and the probability of migration is the same across workers' type.

1.6.2. Non-uniform probability of migration

In the previous subsection we have shown that, if both types of human capital have the same probability of migration, the lagging country achieves full convergence and the steady-state distance to frontier is \tilde{a}_l . When the probabilities of migration differ across skill types, however, workers' incentives to accumulate skills are distorted to an even larger extent.

The analysis here parallels the analysis performed above for the case of uniform probabilities, with the exception that we assume that G -skilled workers, being more productive in innovation, will be more demanded in the frontier country than T -type workers and will accordingly face a higher probability of migration, i.e. we assume that $p_G > p_T$. Let us first rewrite 1.15, allowing for different probabilities of migration in different sectors:

$$(1.16) \quad (p_T a_{t-1} \bar{\omega}_{Tt} + (1 - p_T) \omega_{Tt}) \xi = (p_G a_{t-1} \bar{\omega}_{Gt} + (1 - p_G) \omega_{Gt}) j'.$$

As in the previous case, the probability of migration distorts the accumulation of human capital and reduces the growth rate, all else equal. Here, however, the fact that p_G is larger than p_T increases the expected value of accumulating G -skills to a larger degree. One of the consequences is that, in this case, the distortion affects the accumulation of skills also

²¹This can be easily seen from expression 1.19 in the Appendix. The introduction of migration makes technicians scarcer and reduces the relative wage faced by firms, since $\sigma > \phi$ this signifies an increase in the threshold level \tilde{a}_h .

when the distance to frontier equals \tilde{a}_l . Indeed, from equation 1.16, it is apparent that, even when workers face the same wages per unit of effective labour both at home and abroad ($\bar{\omega}_G$ and $\bar{\omega}_T$), the relative wage perceived by potential migrants is higher than $\bar{\omega}^*$, causing an over-supply of G -skills.

Moreover, the conclusions from Proposition 1.4 also hold in this case, and are further reinforced by the positive difference between p_G and p_T . Thus, the growth rate decreases further relative to the case where the probability of migration is expressed by the common p . From these two observation we can derive the following:

Proposition 1.6. *When migration of skilled workers is possible, and $p_G > p_T$, the steady-state distance to frontier of the sending economy increases. Moreover, complete specialization in innovation is never achieved by the lagging country.*

Proof. See the Appendix at the end of this chapter . □

We use Figure 1.8 to complete the discussion of this case. The line M_2 in the Figure lays strictly below the M line, which represents the growth rate without migration possibilities. However, based on our discussion above, we know that this line also lies below the line, M_1 , that we used in Figure 1.7 to illustrate the case of common p .

The mechanism at work is the same as before: far away from the frontier it pays to concentrate skills in imitation, since this is the most profitable activity. The decrease in the distance to frontier, however, reduces the productivity gap between imitation and innovation. When the productivity gap has decreased enough, we observe a switch away from pure imitation. This happens for a value of a equal to $\tilde{a}_{h2} > \tilde{a}_{h1} > \tilde{a}_h$, given the existence of larger distortions in this context (the possibility of migrating *and* the different probabilities of doing so).

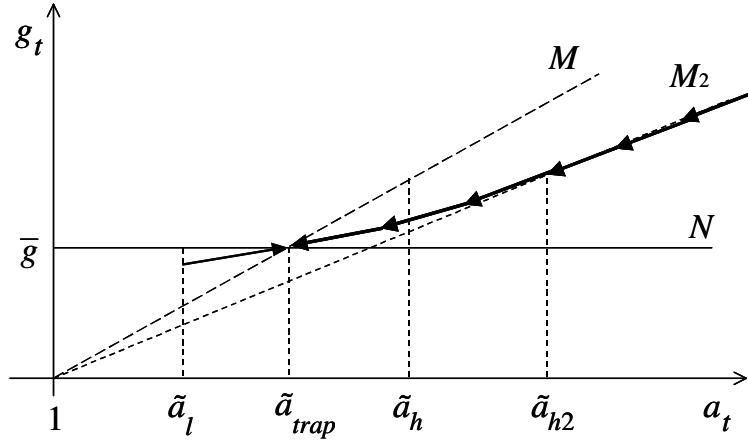


Figure 1.8. *No convergence with migration, and $p_G \neq p_T$.*

That the economy is distorted to a larger degree, finally, is evident from the fact that the lagging country experiences a *development trap* in this case. The fact that generalists are more favoured in migration means that technical skills become scarcer in the source country also at \tilde{a}_l . Thus the growth performance of the lagging country cannot exceed the growth performance of the leading country (which is the speed of expansion of the frontier) at \tilde{a}_l . By the continuity of the function expressing the growth rate, and the fact that it increases with the distance to frontier (see the Appendices for the details) we conclude that the process of convergence towards the frontier must stop short of \tilde{a}_l . We identify this long-run rest-point of the system by \tilde{a}_{trap} in the Figure 1.8, to emphasize the suboptimal nature of this outcome. Despite having the potential to reach the frontier, the distortions induced by the workers' migration prospects lock the country in a vicious circle of inappropriate accumulation of skills, lower economic growth (relative to potential) and persistently larger distance from the frontier.

1.7. The role of subsidies in the process of development

In the previous sections we have shown the effects of human capital's composition on the rate of economic growth and the potential convergence of a developing country. We

concluded that the prospect of migration distorts the composition of human capital in the lagging countries and that, as a consequence, the brain drain translates into smaller growth rates and, potentially, into steady-states with larger gaps from the technological leaders.

A natural concern for policymakers in developing countries might then be to design policies aimed at correcting the distortions, and at adjusting the formation of human capital to the needs of local entrepreneurs. In this section we investigate one such instrument: targeted subsidies to education.

Under migration, the composition of human capital is suboptimal from the lagging country perspective, thus subsidies might be used as additional incentives to adopt the ‘appropriate’ type of skills. To off-set the negative impact of brain drain on human capital composition, policymakers in the lagging country could consider subsidizing the acquisition of technical education or, which is equivalent, taxing general skills. Without loss of generality, in what follows we consider subsidies to technical education.

Formally, we present subsidies as an increase in the returns to this type of education. Workers offering ξ units of technical skills on the market will receive a compensation of $w_T \xi(1 + \tau)$, where $\tau > 0$ is the subsidy rate. Our modelling of subsidies provides a rather general representation of monetary transfers, in fact, every agent of type T works the same hours, and thus receives the same amount of subsidies.

To see how the subsidy to technical education corrects the distortionary effects of the possibility of migration, consider Figure 1.9.

In the Figure we draw the expected income of agents accumulating T - and G -skills as a function of the agent’s type, $j \in [0, 1]$. Investment in T -skills requires $(1 - \xi)$ units of time, irrespective of the agent’s type. Hence, labour income equals $w_T \xi$ for any agent. The cost of accumulating G -skills, instead, depends on the type of the agent. An agent indexed by

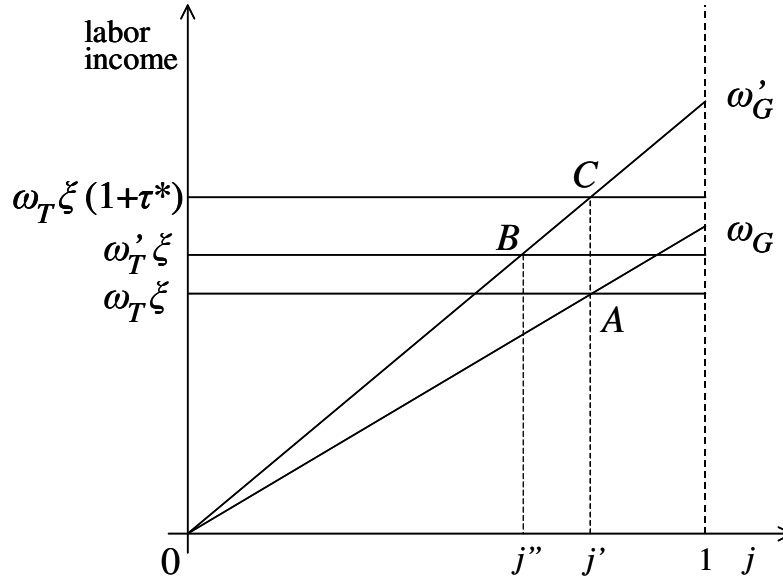


Figure 1.9. *Effects of a subsidy (τ) to technical education.*

j must spend $(1 - j)$ units of her time to accumulate capital. She can subsequently derive an income equal to $w_G j$ from her skills. Point A , the point where the horizontal $w_T \xi$ line crosses the sloping $(0 - w_G)$ one, identifies j' , the agent who's indifferent between the two types of skills. This point also determines the supply of G and T skills according to 1.3 and 1.4.

In the absence of migration, this point determines the optimal supply (and composition) of skills. When migration possibilities enter the picture, however, expected wages increase for both skill types, and both schedules shift up. The wages raise from w_G to w'_G and w_T to w'_T . However, since G -skills are relatively more rewarded abroad, the upwards shift in the sloping line is more marked, the relevant curves now cross in B , and the indifferent agent has a lower index: j'' . Accordingly, the supply of G -skills increases, while that of T -skills decreases. This yields a suboptimal result in terms of the availability of skills for domestic firms. As discussed in previous sections, this results in a reduction of the growth rate and, when $p_G > p_T$, in an increase of the long-run distance to frontier: a development trap.

Increasing the returns to accumulating technical skills tends to correct the distortion caused by the migration prospects. The provision of a subsidy increases the wages of T -skilled workers, and raises the horizontal line in the Figure further up. When the subsidy is set optimally, the indifferent agent is once again indexed by j' . Since the subsidy does not distort the demand for skills, this is sufficient to represent optimum. For that to be the case, however, τ must be set equal to

$$(1.17) \quad \tau^* = \frac{\omega_{T\text{no-}\mu}}{\omega_{G\text{no-}\mu}} \cdot \frac{p_G a_{t-1} \bar{\omega}_{Gt} + (1 - p_G) \omega_{Gt}}{p_T a_{t-1} \bar{\omega}_{Tt} + (1 - p_T) \omega_{Tt}} - 1,$$

where the ‘no- μ ’ subscript indicates the optimal wages without migration. When technical education is subsidized according to this rule, that is when $\tau = \tau^*$, the marginal agent j' faces the same expected relative returns to accumulating skills, irrespective of the regime of international mobility.

Notice that, since the strength of the distortion increases with the distance to frontier, the optimal subsidy τ^* is an increasing function of a_{t-1} . Indeed, recall that the relative wage ω_t decreases with the distance to frontier, going from $\bar{\omega}^*$ to ω^* , as can be clearly seen from Figure 1.4; thus, $\omega_{T\text{no-}\mu}/\omega_{G\text{no-}\mu}$ increases with a_{t-1} . Moreover, the relative domestic wage ω_{Gt}/ω_{Tt} decreases with the distance to frontier, as the productivity of G -skills decreases with the decreasing weight of innovation relative to imitation. Finally, $p_G > p_T$. Thus, also the second ratio at the right-hand side of 1.17 increases with a_{t-1} .

As the process of development and convergence to the frontier proceeds, the rate of the subsidy necessary to restore the optimal trajectory declines over time to satisfy 1.17 at each instant (and at each level of the distance to frontier a_{t-1}). We can summarize this discussion in the following result:

Proposition 1.7. *When technical skills are subsidized according to (1.17), the optimal accumulation of skills is restored. Moreover, the optimal subsidy rate τ^* declines over time, as the technological frontier draws nearer.*

Proof. In the text. □

Thus, subsidizing technical education when the prospects of migration might distort accumulation incentives on the part of workers corrects the incentives and restores optimum. We view this implication of our model as an interesting rationalization of the policies performed by the successful East-Asian economies that we discussed in Section 1.2. There the state invested in specific types of tertiary education, with the aim of aiding local employers. The implications of the model, moreover, seem consistent with the evolution of the attitude of the policymakers responsible for educational policy mentioned by some observers. The shift from interventionism to *laissez-faire* is in line with our story: when the structure of the economy changes to match that of the leading economies, direct interventions in education, to regulate the structure of the supply of skills become redundant, and market mechanisms regain center stage.

1.8. Conclusions

The debate on the economic effects of the brain drain has not yet reached clear conclusions. This is particularly true for studies focusing on developing countries. Recent empirical contributions (e.g. Beine, Docquier, and Rapoport, 2004) have argued that among developing countries there seem to be both winners and losers, suggesting the need for more theoretical work aimed at understanding any patterns.

Building on these ideas, we develop a simple theoretical model to investigate whether the prospects of migration have an influence on growth and convergence. Our contribution

extends the framework of Vandebussche, Aghion and Meghir (2004) to incorporate the endogeneity of human capital accumulation in a model where growth is driven by technical progress, and technical progress is the result of purposive activities of imitation and of *bona fide* innovation. The main insight from the model is that, at different levels of development, different types of human capital, or rather different proportions thereof, are needed to achieve optimal growth. Thus, the key determinant of the optimal composition of skills in any given economy is its distance from the technological frontier.

By blurring the borders between economic systems at different levels of development, the possibility of migration distorts price signals, induces change in the accumulation of human capital, and ultimately proves detrimental for developing countries. We find that the brain drain reduces the growth rate of a developing country along the transition to its long-run balanced growth path. Moreover, we point at the possibility of the emergence of development traps, as the opportunities of migration might reduce the long-run income level of lagging countries.

Our theoretical contribution also provides some normative conclusions that might shed more light on the astonishing performance of the most successful East Asian economies over the past few decades. From our positive analysis we know that some types of human capital are more important for the developing countries, but the incentives to acquire them are reduced by the prospects of migration. Hence, on the normative side, we show that a very important role can be played by government interventions, e.g. in the form of subsidies that encourage the acquisition of those particular skills which are most needed domestically. Moreover, since the distortionary impact of the migration prospects decline with the proximity to the frontier, the government's support in favor of certain skills should taper off as the development process proceeds.

We find this story particularly useful, as it can be used to rationalize the behaviour of the successful East Asian economies over their path to development. Countries like Japan, the Republic of Korea, Taiwan and Singapore all experienced both high rates of GDP growth and of brain drain at the same time: a puzzling story, at first sight. However, they are also quoted as examples of the government's intervention in the educational field, where policies were aimed at favouring the acquisition of technical skills over other skills. According to our story, these policies might have helped the growth performance of Japan and of the Asian Tigers by correcting the distortionary impacts induced by the brain drain. We find more support for the predictive power of our analysis in the fact that more recently the same countries are advocating a pervasive change in their educational strategies, to favour the direction of market forces in education composition. This corresponds to the policy a regulator in our model who would find such a change optimal once the technological frontier has been reached.

Our analysis, however, raises a number of questions, the most obvious of which refers to the empirical relevance of the mechanisms we identify. We present some stylized facts and anecdotal evidence supporting our theory, yet, a more thorough empirical analysis is called for by our results. Among our plans for future work is testing the implications of the model in a formal setting.

Appendix

Proof of Proposition 1.1

Firms maximize profits choosing employment in productivity-enhancing activities, taking wages as given:

$$\begin{aligned}
 (1.18) \quad \max_{\{T_{mt}, T_{nt}, G_{mt}, G_{nt}\}} \pi_t &= \zeta \left[1 + T_{nt}^\phi G_{nt}^{1-\phi} + (a_{t-1} - 1) T_{mt}^\sigma G_{mt}^{1-\sigma} \right] \\
 &\quad - \omega_{Gt} (G_{mt} + G_{nt}) - \omega_{Tt} (T_{mt} + T_{nt}), \\
 s.t. \quad T_{mt} &\geq 0, \quad T_{nt} \geq 0, \quad G_{mt} \geq 0, \quad G_{nt} \geq 0.
 \end{aligned}$$

Where we have normalized the expression for profits using the distance to frontier A_{t-1} , letting $a_{t-1} \equiv \bar{A}_{t-1}/A_{t-1}$. From the first-order conditions of this problem, we know that, for every level of the relative wages, the relative demand for skills in innovation and imitation must satisfy

$$\frac{T_{nt}}{G_{nt}} = \left(\frac{\phi}{1-\phi} \frac{\omega_{Gt}}{\omega_{Tt}} \right), \text{ and } \frac{T_{mt}}{G_{mt}} = \left(\frac{\sigma}{1-\sigma} \frac{\omega_{Gt}}{\omega_{Tt}} \right).$$

Plugging these back into 1.18, we obtain the following alternative expression:

$$\begin{aligned}
 \pi_t = \zeta \left[\left(\frac{\phi}{1-\phi} \frac{\omega_{Gt}}{\omega_{Tt}} \right)^\phi G_{nt} + (a_{t-1} - 1) \left(\frac{\sigma}{1-\sigma} \frac{\omega_{Gt}}{\omega_{Tt}} \right)^\sigma G_{mt} \right] &- \omega_{Gt} (G_{nt} + G_{mt}) + \\
 - \omega_{Tt} \left(\frac{\phi}{1-\phi} \frac{\omega_{Gt}}{\omega_{Tt}} G_{nt} + \frac{\sigma}{1-\sigma} \frac{\omega_{Gt}}{\omega_{Tt}} G_{mt} \right).
 \end{aligned}$$

The necessary conditions for a maximum read:

$$\begin{aligned}
 (1-\phi) \left(\frac{\phi}{1-\phi} \frac{\omega_{Gt}}{\omega_{Tt}} \right)^\phi &\leq \omega_{Gt}, & \left[(1-\phi) \left(\frac{\phi}{1-\phi} \frac{\omega_{Gt}}{\omega_{Tt}} \right)^\phi - \omega_{Gt} \right] G_{nt} &= 0; \\
 (a_{t-1} - 1)(1-\sigma) \left(\frac{\sigma}{1-\sigma} \frac{\omega_{Gt}}{\omega_{Tt}} \right)^\sigma &\leq \omega_{Gt}, & \left[(a_{t-1} - 1)(1-\sigma) \left(\frac{\sigma}{1-\sigma} \frac{\omega_{Gt}}{\omega_{Tt}} \right)^\sigma - \omega_{Gt} \right] G_{mt} &= 0.
 \end{aligned}$$

An interior solution for this problem obtains when the left-end sides of both inequalities above equal ω_{Gt} . Thus, both activities occur in equilibrium whenever

$$(1.19) \quad a_{t-1} = 1 + \frac{1-\phi}{1-\sigma} \left(\frac{1-\sigma}{\sigma} \right)^\sigma \left(\frac{\phi}{1-\phi} \right)^\phi \omega_t^{\phi-\sigma} \equiv \tilde{a}(\omega_t).$$

That is, for every value of $\omega_t \equiv \omega_{Gt}/\omega_{Tt}$, there exists a unique value of a_{t-1} , such that an interior solution obtains. In other terms, the solution is characterized as follows:

$$(1.20) \quad \text{if } a_{t-1} \begin{cases} < \tilde{a}(\omega_t) & \Rightarrow \text{innovation only;} \\ = \tilde{a}(\omega_t) & \Rightarrow \text{innovation and imitation;} \\ > \tilde{a}(\omega_t) & \Rightarrow \text{imitation only.} \end{cases}$$

However, from the discussion of the equilibria in Section 4, we know that at any equilibrium, the wage rate must lay in the interval $[\omega^*, \bar{\omega}^*]$. This implies bounds for the range of the values of a_{t-1} for which interior solutions may occur in the equilibrium. Let the lower bound of the interval be $\tilde{a}_l = \tilde{a}(\bar{\omega}^*)$ and the upper bound be $\tilde{a}_h = \tilde{a}(\omega^*)$.

Then, from 1.20, we can conclude that when $a < \tilde{a}_l$ only innovation occurs. While $a_{t-1} > \tilde{a}_h$, implies that firms only resort to imitation. For the intermediate range, $a_{t-1} \in (\tilde{a}_l, \tilde{a}_h)$, the equilibrium is characterized by firms performing both imitation and innovation. \square

Proof of Proposition 1.2

Recall equation 1.7,

$$A_t = A_{t-1} + A_{t-1} T_{nt}^\phi G_{nt}^{1-\phi} + (\bar{A}_{t-1} - A_{t-1}) T_{mt}^\sigma G_{mt}^{1-\sigma};$$

the growth rate is:

$$(1.21) \quad g_t \equiv \frac{A_t - A_{t-1}}{A_{t-1}} = T_{nt}^\phi G_{nt}^{1-\phi} + (a_{t-1} - 1)T_{mt}^\sigma G_{mt}^{1-\sigma}.$$

The market solution implies that wages equal the marginal products of the two types of skills in both activities, using $G_{nt} + G_{mt} = G_t$ and $T_{nt} + T_{mt} = T_t$, we write this as:

$$\omega_{Gt} = (1 - \phi)T_n^\phi G_n^{-\phi} = (a_{t-1} - 1)(1 - \sigma)(T_t - T_{nt})^\sigma (G_t - G_{nt})^{-\sigma};$$

$$\omega_{Tt} = \phi T_{nt}^{\phi-1} G_{nt}^{1-\phi} = (a_{t-1} - 1)\sigma(T_t - T_{nt})^{\sigma-1} (G_t - G_{nt})^{1-\sigma}.$$

Focusing on imitation, this implies:²²

$$\frac{\omega_{Gt}}{\omega_{Tt}} = \frac{1 - \sigma}{\sigma} \left(\frac{T_t - T_{nt}}{G_t - G_{nt}} \right).$$

In the absence of migration, this ratio must equal 1.3 in equilibrium, i.e.

$$(1.22) \quad \frac{1 - \sigma}{\sigma} \left(\frac{T_t - T_{nt}}{G_t - G_{nt}} \right) = \frac{\xi}{\sqrt{1 - 2} G_t}.$$

Let G_t^* be the growth maximizing value of G_t :

$$G_t^* = \arg \max g_t = \arg \max T_{nt}^\phi G_{nt}^{1-\phi} + (a_{t-1} - 1)(T_t - T_{nt})^\sigma (G_t - G_{nt})^{1-\sigma};$$

²²This is without loss of generality, focusing on innovation yields equivalent results.

since g_t is strictly concave and continuous, and T_t is a function of G_t according to 1.4, the sufficient condition for a maximum reads:

$$(1.23) \quad \frac{1 - \sigma}{\sigma} \left(\frac{T_t - T_{nt}}{G_t - G_{nt}} \right) = - \frac{\partial T(G_t)}{\partial G_t}.$$

From 1.4, it is straightforward that

$$- \frac{\partial T(G_t)}{\partial G_t} = \frac{\xi}{\sqrt{1 - 2G_t}}.$$

Hence, 1.23 becomes

$$\frac{1 - \sigma}{\sigma} \left(\frac{T_t - T_{nt}}{G_t - G_{nt}} \right) = \frac{\xi}{\sqrt{1 - 2G_t}}.$$

Since this expression is identical to 1.22, we conclude that the market outcome is growth maximizing. □

Proof of Proposition 1.3

From Proposition 1.1 we know that the lagging country can be in any of three situations: it can be performing innovation only (when $a \leq \tilde{a}_l$), it can be engaging in both innovation and imitation (when $a \in (\tilde{a}_l, \tilde{a}_h)$), or it can be fully specialized in imitation (when $a \leq \tilde{a}_h$). Under the innovation-only regime, the lagging country is, by symmetry, identical to the technological leader, and its growth rate will then be \bar{g} , a constant. If imitation and innovation coexist at the optimum, the growth rate will be given by 1.21. Proposition 1.2 shows that for each level of a_{t-1} , this function is maximized by the solution of our model. Moreover, the function in 1.21 is continuously differentiable in $a \in (\tilde{a}_l, \tilde{a}_h)$. Thus, applying

the envelope theorem yields:

$$\frac{\partial g_t}{\partial a_{t-1}} = T_{mt}^\sigma G_{mt}^{1-\sigma} > 0$$

In the imitation-only case, equation 1.21 reduces to

$$(1.24) \quad g_t = (a_{t-1} - 1)T_t^\sigma G_t^{1-\sigma},$$

and the same reasoning goes through. We can conclude that the growth rate of the lagging economy increases with the distance to frontier and is higher than the rate of frontier expansion at each point where $a > \tilde{a}_l$. \square

Proof of Proposition 1.5

First notice that when $p_G = p_T = p$ the labour supply of the lagging country, implicitly defined by 1.15, coincides with the one for the leading economy whenever $\omega = \bar{\omega}$. In this case, by symmetry, the two economies are identical and their growth rates are also equal. Hence when the lagging country, has a distance to frontier equal to \tilde{a}_l , it specializes in innovation, and will grow at the same rate as the leading economy: $g_t = \bar{g}$.

Whenever $a_t \in (\tilde{a}_l, \tilde{a}_h)$, both innovation and imitation occur at the same time. The growth rate of the economy is then:

$$g_t(\cdot) = T_{nt}^\phi G_{nt}^{1-\phi} + (a_{t-1} - 1)T_{mt}^\sigma G_{mt}^{1-\sigma}.$$

In the presence of migration, the equilibrium level of G and T , and the split thereof, will not be the same as without migration, hence the growth rate will not be maximized.

Differentiating the above expression with respect to a_{t-1} yields:

$$(1.25) \quad \begin{aligned} \frac{dg_t}{da_{t-1}} = & \phi T_{nt}^{\phi-1} G_{nt}^{1-\phi} \frac{\partial T_{nt}}{\partial a_{t-1}} + (1-\phi) T_{nt}^{\phi} G_{nt}^{-\phi} \frac{\partial G_{nt}}{\partial a_{t-1}} + (a_{t-1}-1) \sigma T_{mt}^{\sigma-1} G_{mt}^{1-\sigma} \frac{\partial T_{mt}}{\partial a_{t-1}} + \\ & + (a_{t-1}-1)(1-\sigma) T_{mt}^{\sigma} G_{mt}^{-\sigma} \frac{\partial G_{mt}}{\partial a_{t-1}} + T_{mt}^{\sigma} G_{mt}^{1-\sigma}. \end{aligned}$$

At any interior equilibrium it must be the case that $\phi T_{nt}^{\phi-1} G_{nt}^{1-\phi} = (a_{t-1}-1) \sigma T_{mt}^{\sigma-1} G_{mt}^{1-\sigma} = \omega_{TGt}$, and $(1-\phi) T_{nt}^{\phi} G_{nt}^{-\phi} = (a_{t-1}-1)(1-\sigma) T_{mt}^{\sigma} G_{mt}^{-\sigma} = \omega_{Gt}$. Moreover, since $T = T_{mt} + T_{nt}$, it follows that $\partial T_{nt}/\partial a_{t-1} = \partial T_t/\partial a_{t-1} - \partial T_{mt}/\partial a_{t-1}$; a similar expression holds for G_t , G_{mt} and G_{nt} . Using these facts into 1.25, we obtain,

$$\frac{dg_t}{da_{t-1}} = \omega_{Tt} \frac{\partial T_t}{\partial a_{t-1}} + \omega_{Gt} \frac{\partial G_t}{\partial a_{t-1}} + T_{mt}^{\sigma} G_{mt}^{1-\sigma}.$$

Recalling the expression linking the supply of T -skills to G_t , from equation 1.4, we can rewrite $\partial T_t/\partial a_{t-1}$ as,

$$\frac{\partial T_t}{\partial a_{t-1}} = -\frac{1}{\sqrt{1-2G_t}} \frac{\partial G_t}{\partial a_{t-1}}.$$

Plugging this into the expression for dg_t/da_{t-1} finally gives us,

$$(1.26) \quad \frac{dg_t}{da_{t-1}} = \left[\omega_{Gt} - \frac{\omega_{Tt}}{\sqrt{1-2G_t}} \right] \frac{\partial G_t}{\partial a_{t-1}} + T_{mt}^{\sigma} G_{mt}^{1-\sigma} > 0,$$

since both terms are always positive. Indeed, as discussed in section 6.1, the term in square brackets is always negative since the supply curve under migration, and hence the equilibrium value of the wage rate ω , lies below the supply curve relative to the no migration case. Recalling footnote 19 this implies $\omega_t < \omega_{no-\mu}$, or $\omega < \xi/\sqrt{1-2G_t} < 1/\sqrt{1-2G_t}$. Since $\partial G_t/\partial a_{t-1} < 0$ because the equilibrium level of G_t decreases with ω_t , while ω_t decreases with

the distance to frontier, the first term is always positive. The positivity of the second term at the right-hand side, on the other hand, is trivial.

To conclude the proof notice that when only imitation occurs by a similar reasoning we immediately get 1.26, by setting $T_{mt} = T_t$ and $G_{mt} = G$.

Thus, we have shown that the lagging economy grows faster than the leading one for each level of the distance to frontier larger than \tilde{a}_l , while it grows just at the same rate as the frontier when full specialization in innovation (i.e. convergence) is finally achieved. \square

Proof of Proposition 1.6.

Notice that the proof in Proposition 1.5 that the growth rate of the lagging economy increases with the distance to frontier holds irrespective of the values of p_G and p_T . Hence, also in this case we can conclude that g increases monotonically with a . Thus, there is a tendency for the technologically lagging country to converge.

To prove that the process stops prematurely when the probability of migration is different for workers with different types of skills, recall 1.16. If the distance to frontier were \tilde{a}_l and firms in the lagging country were to specialize in innovation, by symmetry, domestic wages would equal foreign ones. Contrary to before though, the two economies are not identical, given the wedge induced by the different probabilities of migration. Thus the accumulation of human capital is distorted. From Proposition 1.2, the growth rate is maximized in the leading country. Since g is strictly concave and continuous, it follows that the growth rate that can be obtained for \tilde{a}_l by the lagging country can only be smaller than \bar{g} .

Since the growth rate increases monotonically with a , it follows immediately that the lagging country will stop converging towards the frontier at a level of the distance to frontier

$$a_{trap} > \tilde{a}_l.$$

Thus, the steady-state distance to frontier is increased by the possibility of migration and that no specialization in innovation is possible in this case. \square

CHAPTER 2

Brain Drain and Investments

2.1. Introduction.

This chapter provides additional insight in associating the international migration of human capital (brain drain) with reduction of barriers for international flow of capital and ideas; barriers that emerge due to cross-country cultural differences. In particular, this chapter shows that for investors in technologically advanced countries the brain drain can act as a positive signal of capabilities of foreign workers. In turn, this signal reduces the barriers for international investments flows, technologies and knowledge, that arise from international cultural differences and resulting imperfect information about the actual quality and appropriateness of foreign human capital.

Recently, the expansion of the service sector, globalisation, and the emergence of new information technologies have increased the role of intellectual assets (such as knowledge, ideas or technologies) in economic activity. In fact, as reported by the OECD (2008a), these intellectual assets have become strategic factors for value creation by firms. They are increasingly important in raising efficiency, and are the core part of market expansion and innovation processes. Thus, the intellectual assets that are embodied in firms technologies (blueprints, knowledge, etc.) become nowadays central to economic development.

At the same time, the issue gains in importance because of the role of foreign direct investments (FDI) in international mobility of intellectual assets. Several theoretical studies (e.g. Mattoo, Olarreaga and Saggi, 2004) suggest and empirical studies (e.g. Blomström

and Kokko, 1997) confirm the strong and positive dependence between the volume of foreign investments (particularly from technologically advanced countries) and the growth of productivity in the country where the investment took place. This is not surprising, since foreign direct investments also result in the transfer of methods of management, organization and know-how used in further production. Referring to Easterly's example of Bangladeshi-Korean cooperation, Daewoo's investment eventually led to a spillover of knowledge. *The story of the birth of the Bangladeshi garment industry illustrates the principle that investment in knowledge does not remain with the original investor. Knowledge leaks.*¹

The dramatic increase in importance of disembodied, intellectual assets such as ideas, technologies and knowledge puts forward the question about the barriers for international flow of technologies. In fact, their growing share in global value chains together with the observed persistence of income inequalities across the world can be a puzzle for economists, since the disembodied character of ideas, technologies and knowledge implies high international mobility of these factors, which in turn should promote the reduction of income differences.

One of the reasons for the persistent character of income inequalities that is postulated in the literature referenced in this chapter is the presence of cross-country cultural barriers for flow of ideas, technologies and knowledge. Indeed, a company wishing to enter foreign markets with its technology, takes into account the potential appropriateness of foreign inputs in production such as local human capital or business environment. The potential incompatibility of foreign inputs (such as skilled workers), which could result from cultural heterogeneity, can thus hinder the flows of technologies and knowledge.

¹Easterly, (2002), p. 148.

Here we postulate that brain drain can act as a positive signal for investors that resolves the potential uncertainty about the appropriateness of foreign human capital. In particular, we concentrate on the relationship between brain drain, investments, technological transfer as the channel that helps the sending countries. Given the cultural differences across the countries, firms in the technologically advanced countries are not certain if foreign human capital is a good complement for their intellectual assets such as technologies and knowledge, and hence do not want to engage in an uncertain foreign investment process. The brain drain resolves this uncertainty. Thus, the brain drain acts here as a channel of transfer of information about the appropriateness of foreign human capital.

A policy recommendation to policymakers in the lagging country that follows from our study concerns establishing an environment which facilitates the adoption of foreign technologies through encouraging FDI inflows. These solutions should be tailored and the presence of skilled diaspora abroad should be considered as one of the factors that could leverage the FDI inflows from the technologically advanced countries.

A large part of this chapter's aim is more theoretical in focus. In our model, the appropriateness of inputs from various countries is *ex ante* uncertain, which may be resolved because of brain drain. The (potentially) following foreign direct investments act as a way of direct technological transfer. In addition, a lagging country may try to attract FDI and technological adoption by offering a subsidy scheme.

To reiterate, this chapter indicates that brain drain can attract international transfer of technologies to developing countries by providing a signal to entrepreneurs in the technologically advanced countries on the quality of human capital. The total effect of the brain drain on the sending country is the sum of two opposite types of effects, a positive one (incoming foreign technologies because of better information about cultural adaptability) and

a negative one (loss of human capital) and thus the final impact is ambiguous. Thus this framework also helps in understanding why skilled labor has incentives to move from poor countries to wealthy countries and why this phenomenon does not disturb growth miracles, as observed in some countries.

The chapter is structured as follows. The next section briefly reviews some related literature that debates the problem of cultural barriers for investment flow. Section three introduces a theoretical, general benchmark model, which presents the migration incentives and potential consequences of brain drain on both sending and destination economies. Section four presents stylized empirical facts that illustrate this mechanism. Section five outlines policy recommendations for both countries. The last section concludes.

2.2. Technologies, Cultural Differences, and Migration.

Cultural Distance and FDI

The importance of foreign investments, particularly given their role in disseminating intellectual assets, call for attention about potential barriers for investment flows. The idea that culture and cultural differences may be important for emergence of such barriers for investments and technological transfer has a long and respected lineage and has been stressed many times in the literature. Economic historians such as North (1981) drew attention to the importance of culture and initiated the discussion on the role of cultural factors in the process of growth. In the other stream of the economic literature, the notion of cultural differences (also referred to as *cultural distance*) is referred to different sustainable Nash equilibria that are obtained in repeated games in a given society (Meyerson, 1991; Grief, 1994). Based on their findings several authors (e.g. Spolaore and Wacziarg, 2006; Guiso, Sapienza and Zingales, 2004) notice that culture is one of the key mechanisms allowing for

an explanation of the persistence of economic barriers in the world, that result in limited economic exchange and to some extent support the cross-country income differences.

Regarding the role of culture in influencing foreign direct investment (FDI) and hence technological transfer, this issue has in recent years been challenged on conceptual and methodological grounds. An interesting piece of evidence about the economic importance of cultural differences is provided by management literature.² Within this branch of literature, so-called cultural distance is the crucial element for understanding the inefficiencies in the process of production when some of the employed inputs originate from different countries. Here, cultural distance reduces the efficiency of use of all input factors, which results in a decrease of the operational benefits, and reduces the ability of a firm to fully exploit its potential in employing some of the foreign inputs (Bartlett and Ghoshal, 1989; Palich and Gonzales - Meija, 1999; Schwartz, 1999).

Another illustrative example of how culture affects international investments and technological flows was provided by Easterly (2002) who presented an example of Korean-Bangladeshi co-operation. In his illustrative case a Korean investor (Daewoo) must devote some resources to train the Bangladeshi workers and managers to familiarize them with his tacit knowledge. To complement the knowledge of Daewoo, its Bangladeshi partner (Desh Ltd.) offered his familiarity with the local market: *"Daewoo and Desh adapted Daewoo's methods to local conditions."* Remarkably, the president of Desh Ltd. was *"a former Bangladeshi official with a lot of international connections."*³

Often, the broad and aggregate term *culture* is on the one side disentangled into smaller components such as egalitarianism, (in)tolerance for abuses of market and political power,

²See Tihanyi et. al (2005) for an overview.

³Easterly, (2002), p. 146.

cultural harmony, etc. and on the other side a number of indices that approximate cultural distance are used to verify the theories on their effect on international flows of investment (e.g. Datta, Herrmann, and Rasheed, 2002; Harzing, 2004; Kirkman et al., 2006; Siegel, Licht and Schwartz, 2008).

Closer to the focus of this chapter, a significant share of the broad concept of cultural distance can be assigned to the human capital related issues. Indeed, a particular aspect of cultural distance in the context of investments is the appropriateness of local human capital (with a particular cultural background) with other intellectual assets of investing company a company such as technologies, organizational culture etc. This can happen if a foreign job applicant has some unknown qualities, that in turn could affect his or her productivity, and that can be discovered *ex ante* only through costly screening process or cannot be detected *ex ante* at all. Thus this uncertainty constitutes an additional costs for the investor that might discourage him or her from investment, given the possibility of inadequacy of local skilled workers and hence lower profits. In fact the cultural (in)adequacy of skilled workers with intellectual assets of an investor can at least partially explain the mechanisms through which distinct cultural orientations act either as an asset or as a liability in influencing investment and technology flows.

Clearly, the problems of cultural distance between human capital and other intellectual assets of a company can be also observed in a domestic labor market. Several authors empirically detected the effect of culture on the matching process on the labor market, when the hired candidates had similar cultural background as the employer. The individual hiring decisions can tend towards an employer's own background, given the imperfection of the screening process and the potential risk of cultural inappropriateness of a given applicant (and hence lower profitability for the company). This induces the potential investors to

rely more on stereotypic cultural perceptions as an indicator for the total productivity of a candidate (Cornell and Welch, 1996; Masters, 2004; Vendrik and Schwieren, 2005).

All in all, the cultural distance constitutes an important barrier to FDI. We suggest that skilled migration forms a signal that could reduce this uncertainty related to the appropriateness of local human capital with investor's intellectual assets.

Brain Drain and FDI

The problem of the brain drain is widely observed across the world. Easterly (2001) estimated that around 70% of graduates in Guyana migrate to the United States. Carrington and Detragiache (1998) showed that over half of secondary and tertiary graduates migrate to the US from such countries as The Gambia, Fiji, El Salvador, Jamaica or Trinidad and Tobago. On the other hand, a growing number of skilled workers in developed countries have completed their education abroad (Lowell, 2001; Borjas, 2005). Although the brain drain was perceived as an explanation of income differences between countries, the newer empirical studies highlight its complex character that results in ambiguous effect on sending countries (Carrington and Detragiache, 1998; Docquier et al., 2005). These studies showed that the percentage of emigrating human capital for many developing economies is surprisingly low,⁴ and that some sending countries are relatively wealthy compared to their neighbors, which report smaller rates of emigration of highly educated individuals.⁵ Although some sending countries indeed report higher per capita income levels than non-sending ones, there are also sending countries that stagnate or do not differ significantly from their non-sending

⁴For example, less than one percent of graduates in Senegal, Bangladesh, Benin, Mali, Paraguay and Togo decide to emigrate.

⁵For example, Taiwan and South Korea observe relatively high rates of brain drain as compared to Bangladesh and Indonesia, while the GDP per capita in these sending countries is much higher than in their non-sending neighbors.

neighbors. This suggests that there is no clear relationship between the rate of the brain drain and per capita income levels of the sending countries.

In this chapter we claim that the brain drain can resolve the uncertainty related to the appropriateness of local human capital with investor's intellectual assets and in turn encourage companies to enter technologically lagging countries. In those cases when an investor learns that the human capital originating from the lagging country was culturally appropriate and thus useful, a potential risk for an investor is lower and hence FDI is more likely to occur.

2.3. The Model.

In the first part of this section, we present the building blocks of the model and we also introduce in a formal way the notion of cultural distance. In the second part of this section we study the international relations between the technologically advanced country and the lagging country, for various cases when international investments and flows of human capital are allowed.

Initially we consider investment incentives in the absence of migration. Then we introduce the possibility of investment and migration when the signal about foreign cultural appropriateness is clear. Finally, we introduce the possibility of migration and analyse its effect on investment flows when the quality of the information signal is not that clear.

2.3.1. Elements of the model

We consider two countries – a technologically advanced country (frontier country) and a lagging country that differ with respect to technology levels and endowment of human and

physical capital.⁶ The model is dynamic, but we focus on only two periods. In each country and each period, there are two types of agents: producers (endowed with physical capital) and skilled workers (endowed with human capital). In particular, in each country i ($i = 1, 2$) there are L skilled workers and N entrepreneurs.⁷ Each entrepreneur in each country owns one firm. Each firm operates for one period and is endowed with physical capital and the technology,⁸ which depends on the country of entrepreneur's origin. In each period, each firm from the advanced country is endowed with given amount of capital k_1 and technology A_1 and each firm from the lagging country is endowed with given amount of capital k_2 and technology A_2 .

The stylized sequence of events looks as follows (all details are presented below). In the first period firms in the advanced country pick a common prior about the distribution of foreign cultural adaptability and nature picks the true cultural adaptability in the lagging country. Then the government in the advanced country chooses the volume of immigrants. Migrants move from the lagging to the advanced country and are hired by firms in the advanced country. The cultural adaptability of migrants is revealed in the process of production and finally firms renegotiate wages paid to labor. At the end of the first period firms are closed and the physical capital is transferred to the second period. In the second period firms are re-established and entrepreneurs in the advanced country update their expectations about the cultural adaptability abroad. Then entrepreneurs from the advanced country choose their level of FDI. Finally investment and subsequently production take place.

⁶Variables related to the lagging country are henceforth denoted with subscript 2. Variables related to the frontier country are henceforth denoted with subscript 1.

⁷Since we introduce later possibilities of investments, we will use the terms *entrepreneurs*, *producers* and *investors* interchangeably.

⁸The technology is endogenous in our setting. The process of technological progress and the resulting cross-country differences in technological stock are discussed later.

2.3.1.1. First period. In the first period, mL ($m \in [0, 1]$) agents are allowed to migrate to the advanced country. Besides, there are no other contacts between the two countries.

Each firm from the advanced country employs $l_1 = L/N$ agents from the advanced country and $l_m = mL/N$ immigrants. Each firm from the lagging country of type 2 employs $l_2 = (1 - m)L/N$ agents from the lagging country.

The human capital from country i may be only fully utilized when matched with the technology from country i . Denote the value of the human capital resulting from matching the agents from the advanced country to the technology from the advanced country by h_1 and the value of the human capital resulting from matching agents from the lagging country with the technology from the lagging country by h_2 .

Concerning the case when human capital and the technology do not originate in one country, the human capital supplied by the agents from the lagging country is not fully compatible with the technology from the advanced country. In our analysis we introduce the cultural distance and the imperfect information in the following way: the cultural differences might result in some inefficiencies of the process of production, when the inputs from both countries are employed together. Particularly, say that between two countries there is an observable cultural distance, that could cause certain inappropriateness of use of inputs of production when employed together. This cultural distance is publicly observable and each agent and entrepreneur is aware of its possible impact on production process. Denote the match efficiency with λ ($\lambda \in (0, 1]$). The greater the distance between the economies, the higher the mismatch, and the lower the value of λ .

However, some agents in the lagging country can adapt themselves to the foreign technology while others cannot. As a result, some agents in the lagging country are more efficient when employed with foreign inputs. This difference in adaptability cannot be observed per

individual, and is revealed only when this worker is matched with the physical capital from the advanced country. In other words, as long as an employee does not work for a foreign company, he or she will never learn whether he or she can adapt to the foreign working conditions and if that company is a relatively good match for him or her.

In terms of the model, with the individual probability $p_\iota \in (0, 1)$ an agent ι from the lagging country will work efficiently when employed together with foreign inputs in production, offering h_2 units of human capital. With probability $(1 - p_\iota)$ the agent will have low adaptability and will be an imperfect complement to the foreign inputs of production, offering only $h_2\lambda$ of effective units of human capital.

Hence, by the law of large numbers in the lagging country the number of people that are adaptable equals $\int_0^L p_\iota d\iota / L \equiv p$ so that p is the fraction in total population of workers in the lagging country that offer h_2 units of human capital, while $(1 - p)$ is the fraction that offers only $h_2\lambda$ of effective units of human capital.

Recall that the investors from the frontier country do not know to what extent the foreign human capital is adaptable as a good complement to their assets. They are aware of cultural distance between the countries (λ), but do not know what is the effective value of a foreign human capital if combined with their inputs. In terms of the model we assume that investors are not certain how large is the share of foreign workers that are well adaptable to their inputs (p), but they form beliefs about p . Denote the ex-ante expected value of p by p_{ex} i.e. $E[p] = p_{ex}$, and the ex-ante expected value of the adaptability of a foreign worker is represented by $E[\Lambda]$, where $E[\Lambda] \equiv p_{ex} + (1 - p_{ex})\lambda$.

Each firm from the advanced country employs l_1 workers from the advanced country and l_m immigrants. A firm from the advanced country produces output (y_1) using local

technology (A_1), local capital (k_1), and the human capital composed of the local agents ($h_1 l_1$) and migrants ($\Lambda_1 h_2 l_m$):

$$(2.1) \quad E[y_1] = A_1(k_1)^\sigma E[(h_1 l_1 + \Lambda_1 h_2 l_m)^{1-\sigma}]$$

Workers offer their labour against a wage (w) and thus are paid according to marginal product of labour. Hence expected profits earned by firms in the advanced country are equal to:

$$(2.2) \quad E[\pi_1] = A_1(k_1)^\sigma E[(h_1 l_1 + \Lambda_1 h_2 l_m)^{1-\sigma}] - w_1 l_1 - w_m l_m$$

Firms in the advanced country choose employment to maximize their profits. The first order conditions are:⁹

⁹Note that:

$$\begin{aligned} \frac{\partial E[(h_1 l_1 + \Lambda_1 l_m h_2)^{1-\sigma}]}{\partial l_1} &= \Sigma_s p_s (1-\sigma) (h_1 l_1 + \Lambda_s l_m h_2)^{-\sigma} h_1, \\ \frac{\partial E[(h_1 l_1 + \Lambda_1 l_m h_2)^{1-\sigma}]}{\partial l_m} &= \Sigma_s p_s (1-\sigma) (h_1 l_1 + \Lambda_s l_m h_2)^{-\sigma} \Lambda_s h_2, \end{aligned}$$

where p_s is the probability of the situation when $\Lambda_1 = \Lambda_s$. Hence, profits earned by firms in the advanced country become:

$$\pi_1 = \sigma A_1(k_1)^\sigma \{ \Sigma_s p_s (h_1 l_1 + \Lambda_s h_2 l_m)^{1-\sigma} \}$$

$$(2.3) \quad \frac{\partial \pi_1}{\partial l_1} = A_1(k_1)^\sigma \frac{\partial E[(h_1 l_1 + \Lambda_1 h_2 l_m)^{1-\sigma}]}{\partial l_1} - w_1 = 0$$

$$(2.4) \quad \frac{\partial \pi_1}{\partial l_m} = A_1(k_1)^\sigma \frac{\partial E[(h_1 l_1 + \Lambda_1 h_2 l_m)^{1-\sigma}]}{\partial l_m} - w_m = 0$$

Substituting the first order condition (2.3) - (2.4) into the profit equation (2.2), we find the following indirect profit function:

$$(2.5) \quad E[\pi_1] = \sigma A_1(k_1)^\sigma E[(h_1 l_1 + \Lambda_1 h_2 l_m)^{1-\sigma}]$$

Workers and producers in the advanced country are aware of the phenomenon of the cultural distance, but neither workers nor producers are able to identify the effective human capital offered by a given worker. Only after the workers from the lagging country work for the firm in the advanced country, the firm and the entrepreneurs learn that a certain fraction of the firm's employees from the lagging country is not fully adaptable. Furthermore, the entrepreneurs also learn how foreign workers fit to the other companies in the advanced country. In particular, suppose that after observing the inputs and final outputs from all the companies, an entrepreneur deduces p_{new} , which denotes the share of migrants that are fully compatible to the local technology and physical capital.¹⁰ In particular, the producers deduce that $p_{new}mL$ migrants offer h_2 units of human capital, while $(1 - p_{new})mL$ migrants offer only λh_2 of effective units of human capital.

¹⁰By the law of large numbers p_{new} converges to p in m .

Firms adjust wage offers and workers are paid their actual marginal products of labor.

Actual profits are then:

$$(2.6) \quad \pi_1 = \sigma A_1(k_1)^\sigma (h_1 l_1 + \Lambda_1 h_2 l_m)^{1-\sigma},$$

where

$$(2.7) \quad \Lambda_1 = p_{new} + (1 - p_{new})\lambda.$$

In the lagging country firms produce output (y_2) using local technology (A_2), local capital (k_2) and the human capital composed of the local agents ($h_2 l_2$):

$$(2.8) \quad y_2 = A_2(k_2)^\sigma (h_2)^{1-\sigma} (l_2)^{1-\sigma}$$

Profits of firms from the lagging country are equal to:

$$(2.9) \quad \pi_2 = A_2(k_2)^\sigma (h_2)^{1-\sigma} (l_2)^{1-\sigma} - w_2 l_2$$

The first order conditions imply that wages paid in the lagging country are equal to:

$$(2.10) \quad w_2 = (1 - \sigma) A_2(k_2)^\sigma (h_2)^{1-\sigma} (l_2)^{-\sigma}$$

At the end of the first period entrepreneurs consume their profits and workers consume the wages they have earned. Besides, producers close their firms and transfer the physical capital to the next period.

2.3.1.2. Second period. At the beginning of the second period producers again establish firms that employ the labor force that is present on the local market. In that period the advanced country does not accept new migrants and the lagging country allows for foreign direct investments. This implies that entrepreneurs from the advanced country can establish their firms either in the advanced country or in the lagging country. In case there was migration in the first stage ($m > 0$), the entrepreneurs from the advanced country can use the information about the observed productivity of the migrants in evaluating the perspective profitability of establishing a firm in the lagging country. The entrepreneurs from the lagging country may only establish their firms in the lagging country. Hence, the origin of the entrepreneur may be different from the place of her firm's operations. To simplify the notation, we will distinguish three types firms: type 1 – a firm that is owned by an entrepreneur from the advanced country and operates in the advanced country, type 2 – a firm that is owned by an entrepreneur from the lagging country and operates in the lagging country and type 3 – a firm that is owned by an investor from the advanced country and operates in the lagging country.

Production

Firms type 1 and 2 operate the same way as in the first period. Regarding type 3 firms, recall that the human capital of agents from country i is fully utilized only when matched with the technology from the same country. The compatibility of the human capital remaining in the lagging country with the technology from the advanced country is not known to firms of type 3. Denote the expected level of the human capital of firm of type 3 by $E[h_3]$, where $E[h_3] = h_2 E[\Lambda_3]$. This ex-ante expected value of human capital employed by firm of type 3 is based on the value of human capital employed by firm of type 2 and adjusted by the

expectations about their adaptability (expressed by parameter $E[\Lambda_3]$). Once firms from the advanced country invest in the lagging country, labour in the lagging country moves between local firms and foreign-owned firms until wages are equalized over these firms ($w_2 = w_3$). Hence, profits of a type 3 firm are equal to:

$$(2.11) \quad E[\pi_3] = A_1(k_1)^\sigma (l_3 h_2)^{1-\sigma} E[\Lambda_3^{1-\sigma}] - w_2 l_3$$

and the first order conditions imply:

$$(2.12) \quad w_2 = (1 - \sigma) A_1(k_1)^\sigma (l_3)^{-\sigma} (h_2)^{1-\sigma} E[\Lambda_3^{1-\sigma}]$$

and hence:

$$(2.13) \quad E[\pi_3] = \sigma A_1(k_1)^\sigma (l_3 h_2)^{1-\sigma} E[\Lambda_3^{1-\sigma}]$$

Labor Market

Now let us turn to the labor market. Recall that mL ($m \geq 0$) represents the volume of migrants allowed to enter the advanced country. Denote by n the fraction of producers from the advanced country to invest abroad.

Consider the advanced country, where only type 1 firms are active. In the second period a single firm of type 1 in the advanced country employs local workers (l_1) and migrant

workers (l_m). Their volumes are given by:

$$(2.14) \quad l_1 = \frac{L}{N(1-n)}$$

$$(2.15) \quad l_m = \frac{mL}{N(1-n)}$$

In the lagging country the remaining labour force ($L(1-m)$) is employed by local firms of type 2 (l_2N) and foreign investors – firms of type 3 (l_3Nn). Thus the total labor market can be described by:

$$(2.16) \quad L(1-m) = l_2N + l_3Nn,$$

where l_3 is defined in (2.18).

Recall that firms of type 2 and 3 pay the same wages to workers they employ (w_2). Equating (2.10) and (2.12) yields:

$$(2.17) \quad \frac{l_2}{l_3} = \left(\frac{A_2(k_2)^\sigma}{A_1(k_1)^\sigma E[\Lambda_3^{1-\sigma}]} \right)^{1/\sigma}$$

Combining the above equation with the labor market constraint in the lagging country (2.16) yields :

$$(2.18) \quad l_3 = \frac{(1-m)L/N}{n + \left(\frac{A_2(k_2)^\sigma}{A_1(k_1)^\sigma E[\Lambda_3^{1-\sigma}]} \right)^{1/\sigma}}$$

FDI no-arbitrage condition

To close the discussion about the model dynamics we outline the formation of investment incentives. Notice that when considering investments abroad, an entrepreneur from the advanced country takes her profits from the domestic investments (π_1) described by (2.6) as a benchmark. If she decides to invest abroad she employs her country specific technology (A_1) and the physical capital (k_1) in the lagging country. She is free to decide how much of foreign workers to employ, but she is unable to distinguish between fully adaptable workers and workers who offer their human capital that is an imperfect complement to her physical capital.

Once firms from the advanced country invest in the lagging country, labour in the lagging country moves between local firms and foreign-owned firms until wages are equalized over these firms ($w_2 = w_3$) and the profits that an investor in a firm of type 3 earns are described by (2.11). Note that the expected profit of a type 3 firm depends on the entrepreneur's belief about the adaptability of foreign human capital with investor's physical capital. Consequently, the investment decision is based on the nominal volume of human capital (h_2) and the degree of cultural inappropriateness (λ). The investor compares her domestic profits (π_1) given by (2.6) with the profits she expects to earn abroad (2.11). This no-arbitrage condition, together with the expression for the volume of labor employed by type 3 firms, l_3 (2.18) and the labor market conditions in the advanced country (2.14) and (2.15) determine the share of firms to invest abroad (n), i.e.:

$$(2.19) \quad n(m) \equiv \frac{1 - \left(\frac{\tilde{h} + m\Lambda_1}{1-m} \right) \frac{1}{E(\Lambda_3^{1-\sigma})^{1/(1-\sigma)}} \left[\tilde{A} \tilde{k}^\sigma E[(\Lambda_3^{1-\sigma})] \right]^{-1/\sigma}}{1 + \left(\frac{\tilde{h} + m\Lambda_1}{1-m} \right) [E(\Lambda_3^{1-\sigma})]^{-1/(1-\sigma)}}$$

where $\tilde{h} = h_1/h_2$ is the ratio of nominal human capital in both countries, $\tilde{k} = k_1/k_2$ is the ratio of physical capital in both countries, Λ_3 is the expected adaptability of human capital employed by type 3 firms ($\Lambda_1 = E[p] + (1 - E[p])\lambda$) and \tilde{A} is the distance to the technological frontier, given by $\tilde{A} \equiv A_1/A_2 > 1$.

To close the general analysis, recall that the expected profits of firm of type 3 are based on the belief about the adaptability of foreign human capital, $\Lambda = p + (1 - p)\lambda$. Note that since p is stochastic, Λ is stochastic as well. Therefore, we introduce the variable Ω that captures the beliefs of entrepreneurs from the advanced country about the adaptability of human capital in the lagging country, given the information set I :

$$(2.20) \quad \Omega \equiv \left(E \left[\Lambda_3^{1-\sigma} \mid I \right] \right)^{1/(1-\sigma)}, 0 \leq \Omega \leq 1.$$

Equations (2.19) and (2.20) allows us to determine which values of Ω will be sufficient to potentially generate investment incentives. This will be the case for:

$$(2.21) \quad \Omega > \left(\frac{\tilde{h} + m\Lambda_1}{(1-m)\tilde{k}\tilde{A}^{1/\sigma}} \right)^\sigma.$$

Figure 2.1 presents the relationship between migration (m), the entrepreneurs' beliefs about the adaptability of human capital in the lagging country (Ω), and its impact on investment incentives.

The upward-sloping line $n = 0$ in Figure 2.1 is determined by equation (2.19). The area above this line corresponds to combinations of migration rates (m) and the entrepreneurs' beliefs about the adaptability of human capital in the lagging country (Ω) that result in investment incentives. Note that there exists a critical value of migration above which there will be no investment incentives (denoted \bar{m}). This is discussed below.

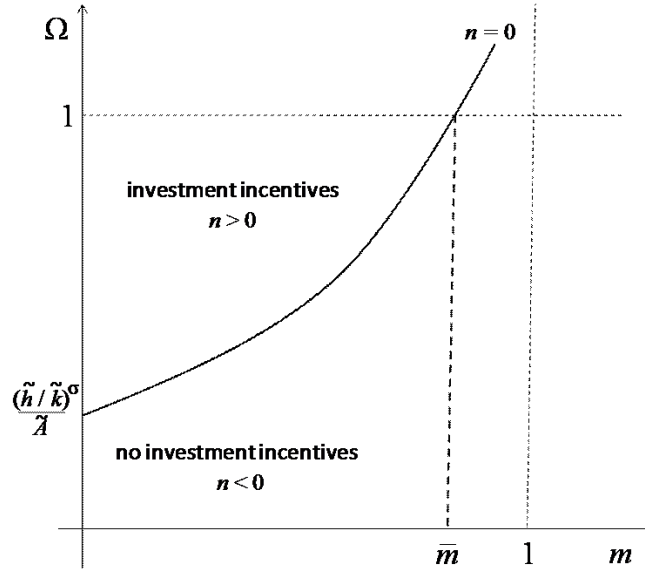


Figure 2.1. Producers' investment incentives as a function of migration (m).

2.3.2. Migration and Investments.

In this part we analyze two cases of possible investments flows from the technologically advanced country to the lagging country. First, we outline the formation of investment incentives when no migration takes place. Then we introduce migration and analyze their effects on formation of incentives to invest.

2.3.2.1. Investments in absence of migration. Suppose that in the first period there was no migration ($m = 0$). In such case, when considering investments abroad in the second period, firm 3 takes her profits from the domestic investments (π_1) described by (2.6) as a benchmark and compares it with the profits she expects to earn abroad ($E[\pi_3]$, defined by (2.11)).

Recall that since in the scenario without migration there is no new information at the start of the second period and thus no additional signal s_t , entrepreneurs will therefore evaluate Ω_t based on their prior beliefs. Substituting (2.20) into (2.19) and setting m equal

to zero we can write the FDI-arbitrage condition in the absence of migration as follows:

$$(2.22) \quad n \equiv \frac{1 - \left(\frac{\tilde{h}}{\tilde{k}} \tilde{A}^{-1/\sigma} \right) \Omega_0^{-1/\sigma}}{1 + \tilde{h} \Omega_0}$$

where

$$(2.23) \quad \Omega_0 = \left(E \left[\Lambda^{1-\sigma} \mid m = 0 \right] \right)^{1/(1-\sigma)}$$

The above equation permits for checking the conditions under which no investment (FDI) takes place. This will be the case for a critically high gap in human capital levels across the countries:

$$(2.24) \quad \tilde{h} \geq \tilde{k} \tilde{A}^{1/\sigma} \Omega^{1/\sigma}$$

or alternatively for the expected adaptability critically small:

$$(2.25) \quad \Omega \leq \left(\tilde{h} / \tilde{k} \right)^\sigma / \tilde{A}$$

Recall the Figure 2.1. Note that in that Figure, the right-hand side expression in (2.25) corresponds to the intersection point of the line $n = 0$ with the vertical axis. All values of Ω below this point represent cases that satisfy the inequality in (2.25) which implies absence of investment incentives.

Figure 2.2 presents the relationship between the differences in nominal human capital (\tilde{h}) and the entrepreneurs' beliefs about the adaptability of human capital in the lagging country (Ω) and its impact on investment incentives.

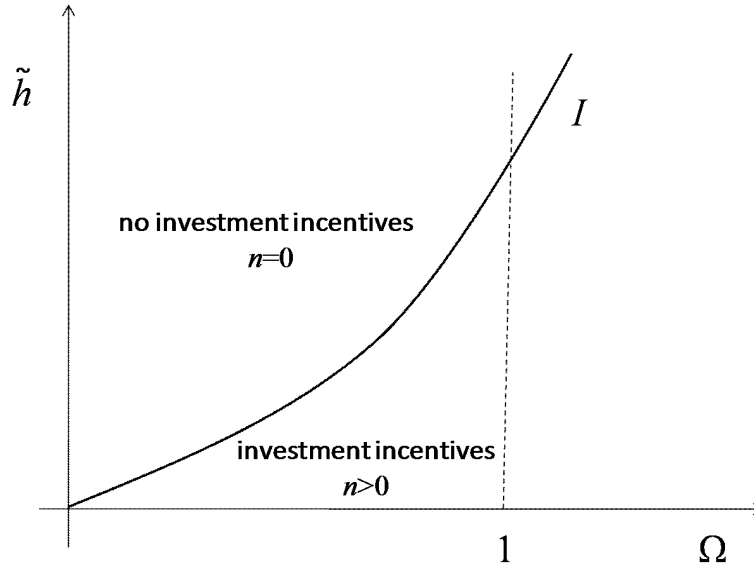


Figure 2.2. Producers' investment incentives.

The horizontal axis represents the expected cultural appropriateness of workers in the lagging country (Ω). The vertical axis stands for the differences in nominal human capital between the countries (\tilde{h}). The upward sloping solid line I is determined by equation (2.24). An investor prefers to invest abroad as long as the foreign human capital offers her expected profits at least as high as the profits she can earn in the technologically advanced country. This can happen as long as the perceived cultural inappropriateness of foreign workers is small and if the observed nominal human capital abroad is at a relatively high level.

Note that conditions (2.24) and (2.25), together with $0 \leq \Omega \leq 1$, imply that if $\tilde{h} \geq \tilde{k}\tilde{A}^{1/\sigma}$ there will be no investments for all possible values of Ω . Put differently, if the nominal value of foreign human capital is relatively small, there will be no investments even for the most optimistic beliefs of producers about foreign adaptability.

Once the observed foreign nominal human capital becomes too small or the cultural inappropriateness of foreign human capital becomes too high, the investor becomes discouraged

from investments which corresponds to the area above the I -line in Figure 2.1. If the observed level of foreign human capital is high and the perceived effects of cultural distance are moderate, investment incentives can emerge (which correspond the area below the I -line in Figure 2.1).

2.3.2.2. Migration and Investments - Large Volumes of Migration. In this subsection we check how migration affects investment incentives. Let the frontier country allow for mL ($m > 0$) inflow of migrants. Once the migrants move to the frontier country, local producers adjust their beliefs about the cultural appropriateness of foreign human capital and invest (or not) abroad. Particularly after the immigrant workers enter the advanced country and work for the type 1 firms, entrepreneurs in the advanced country observe the final output and deduce that $mp_{new}L$ migrants are fully compatible to the local physical capital. This implies that the output of type 1 in the second period will be equal to.

$$y_1 = A_1(k_1)^\sigma (h_1 l_1 + h_2 \underbrace{[p_{new} + (1 - p_{new})\lambda]}_{\Lambda_1} \frac{mL}{(1-n)N} l_2)^{1-\sigma}$$

In the case when migrants that entered the advanced country are perceived to be representative for the skilled human capital in the lagging country, investors could use the observed value of adaptability of foreign workers in the advanced country to induce that the adaptability of workers in the lagging country equals p_{new} . There are two possible cases when investors could perceive that migrants are a good representation of foreign human capital in terms of cultural adaptability. First, it could happen when the entering migrants represent a significant fraction of foreign human capital. In that case m was large enough, so that by law of large numbers p_{new} converged to p . Second if the total population of both countries

is large, so that the volume of entering migrants (mL) was large as well. We focus on the latter case here leaving the former case for the next section.

This subsection studies what happens in cases when migrants that entered the advanced country are perceived as representative for the skilled human capital in the lagging country, and entrepreneurs use their observed adaptability to induce the adaptability of workers in the lagging country equals p_{new} . This value will be used to evaluate the prospective profitability of foreign investments, which will adjust until profits of a firm with firm-specific capabilities k_1 generate the same (expected) profits when producing at home and when undertaking a foreign investment (as described by (2.19)). This is the case when:

$$(2.26) \quad n(m) \equiv \frac{1 - \left(\frac{\tilde{h} + m\Lambda_1}{1-m} \right) \left(\Omega_m \tilde{A} \tilde{k}^\sigma \right)^{-1/\sigma}}{1 + \left(\frac{\tilde{h} + m\Lambda_1}{1-m} \right) \Omega_m}$$

where $\Omega_m \equiv [E(\Lambda_3^{1-\sigma} \mid p_{new})]^{1/(1-\sigma)}$.

Consider scenarios when the ex ante beliefs on the cultural appropriateness of foreign human capital do not generate any investment flows without migration (i.e. Ω_0 is smaller than or equal to the RHS expression of (2.25)) and that the nominal value of foreign human capital is relatively high so that there is a possibility for investments' incentives generation ($\tilde{h} < \tilde{k}\tilde{A}^{1/\sigma}$). As shown in Figure 2.3 in such case, the immigration of skilled workers can initially stimulate investments by positively affecting foreign investors' beliefs about the compatibility of local human capital to investors technology. That is why there is a discrete jump in investment incentives at $m = 0$. When the outflow of migrants further grows, the lagging country becomes less attractive for investors, as its human capital stock becomes scarce. In other words, the foreign investments is a strategic substitute for the emigration

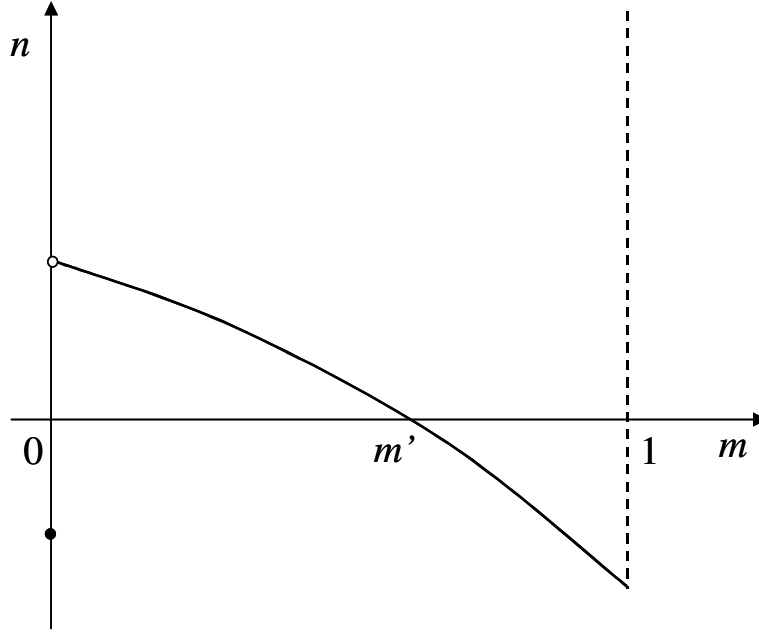


Figure 2.3. Effects of migration (m) on investments (n)

of human capital. Therefore, n decreases with m for $m > 0$. This leads to the following proposition:

Proposition 2.1. *Suppose L is large enough to let Ω_m converge to $p + (1 - p)\lambda$ and suppose that $\Omega_0 < (\tilde{h}/\tilde{k})^\sigma/\tilde{A}$ and $p + (1 - p)\lambda > (\tilde{h}/\tilde{k})^\sigma/\tilde{A}$. Then, two possible effects of brain drain on investments can be observed. First, a small influx of immigrants discretely triggers investments. Second, growing volume of migrants weakens the incentives to invest ($n'(m) < 0$ for $m > 0$).*

Proof. See Appendix A

□

2.3.2.3. Migration and Investments - Small Volumes of Migration. According to the above-presented model, an entrepreneur in the frontier country adjusts instantaneously his or her beliefs about the degree of cultural appropriateness of human capital in the lagging country based on the observed performance of immigrants in production. This update can be

easily performed in particular if the volume of migrants that entered the advanced country (mL) was large enough so that the signal observed by the investors was indeed precise. A precise signal can in turn lead to credible information about the adaptability of native workers in the lagging country and about the profits investors will earn from type 3 firms.

This subsection studies what happens if the entrepreneurs do not believe that the volume of migrants that entered the advanced country is a representative sample for the cultural adaptability of foreign human capital. First, we will present the general case, then we will provide a specific example assuming that entrepreneurs update their beliefs according to Bayes' rule.

General Updating

To analyze the general case, suppose that the volume of migrants that entered the advanced country (mL) was small and the signal, p_{new} , observed by the investors was not precise. This implies that the information about the adaptability of native workers in the lagging country that investors derive based upon this signal is not fully credible and the updated belief about foreign adaptability will therefore depend not only on the observed performance but will also partially rely on the prior belief. Note that the more migrants enter the advanced country the more precise the signal.

In terms of the model suppose that the expected cultural appropriateness of workers in the lagging country (Ω_{new}) will depend not only on the observed performance of immigrants

(p_{new}) but also on their volume (m). In particular assume the following:

$$(2.27) \quad \Omega_{new}(m = 0, p_{new}) = \Omega_0,$$

$$(2.28) \quad \lim_{m \rightarrow 1} \Omega_{new}(m, p_{new}) = p_{new}(1 - \lambda) + \lambda, \text{ and}$$

$$(2.29) \quad \frac{\partial |\Omega_{new}(m, p_{new}) - \Omega_0|}{\partial m} > 0$$

Condition (2.27) implies that for no migration, entrepreneurs will use the Ω_0 value (as defined by (2.23)). This basically reiterates the case introduced above, in the subsection that analyzes the no-migration scenario.

Condition (2.28) implies that for large fractions of agents that enter the destination country, entrepreneurs' ex-post beliefs are formed solely based on the observed migrants' performance. This in turn corresponds to the case presented in the previous subsection, which studied the formation of beliefs for large volumes of migration.

Condition (2.29) implies that for a growing fraction of immigrants (growing m) entrepreneurs tend to a greater extent rely on the observed performance of migrants rather than on their ex-ante beliefs (Ω_0).

Figure 2.4 presents the evolution of entrepreneurs beliefs (Ω_{new}) as a function of migration (m) on the (Ω, m) plane for two possible scenarios. There are three scenarios presented in that Figure. Two, when the observed productivity of migrants implied their adaptability equal to $p_{new,1}$ (one of these scenarios studies the case when mL is large, the other one focuses on the case when mL is small). The last scenario corresponds to the case when the induced adaptability of migrants was equal to $p_{new,2}$ ($p_{new,1} > p_{new,2}$).

In all scenarios lack of migration ($m = 0$) implies that beliefs of entrepreneurs in the advanced country are formed based on their ex-ante expectations (Ω_0). Once migration

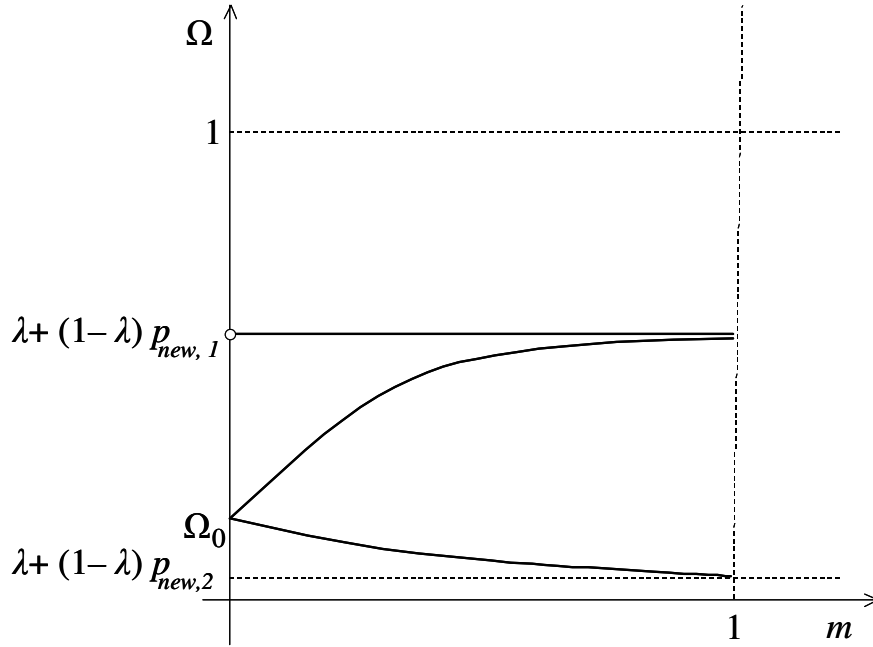


Figure 2.4. Entrepreneurs beliefs (Ω_{new}) as a function of migration (m).

occurs ($m > 0$) entrepreneurs in the advanced country tend to adjust their beliefs about the cultural appropriateness of foreign human capital (Ω). When the induced adaptability of migrants was $p_{new,1}$ and mL was large, entrepreneurs induced instantaneously that the foreign adaptability was equal to $\lambda + (1 - \lambda)p_{new,1}$. In Figure 2.4. this corresponds to the horizontal line at $\lambda + (1 - \lambda)p_{new,1}$. When the adaptability of migrants was equal to $p_{new,1}$ but their volume was small, entrepreneurs in the advanced country slowly adjust their beliefs. Growing m implies that they increase the importance of the observed value $p_{new,1}$ rather than their ex ante beliefs. In Figure 2.4 this corresponds to the curve that begins in Ω_0 and converges to $\lambda + (1 - \lambda)p_{new,1}$. An opposite case occurs when the observed productivity of migrant is low and equals $p_{new,2}$. In such case the entrepreneurs update their beliefs downwards, which in the Figure corresponds to the curve that begins in Ω_0 and converges to the $\lambda + (1 - \lambda)p_{new,2}$ line.

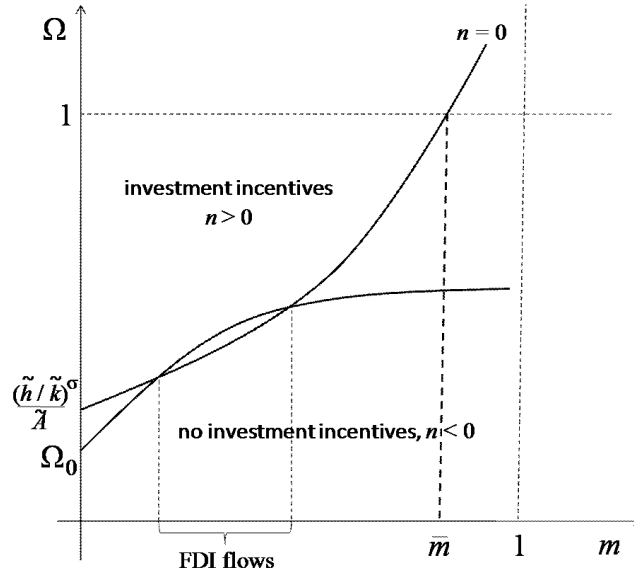


Figure 2.5. Potential emergence of investors' investment incentives.

Recall the Figure 2.1 that presents the emergence of investments' incentives related to entrepreneurs beliefs about foreign adaptability (Ω) and migration rate (m). Consider the second scenario outlined above (small volume of migration mL and the observed performance equal to $p_{new,1}$). This scenario is represented by the curve that for $m = 0$ begins in the point Ω_0 and converges to $\lambda + (1 - \lambda)p_{new,1}$ for m approaching unity. Plotting this curve on Figure 2.1 leads to a conclusion that there could be potential ranges of migration for which FDI incentives could arise. Graphically, this is presented in Figure 2.5.

A small number of migrants does not affect entrepreneurs' beliefs about foreign adaptability and hence cannot trigger migration. Growing number of immigrants results in a stronger adjustment of entrepreneurs beliefs and thus in a potential emergence of investments' incentives. However, rising immigration also affects the firms' incentives to invest in the lagging country by reducing the pool of workers in the lagging country and increasing

the pool of workers in the advanced country. Therefore for large values of migration to the frontier country (m) firms from that country will not have FDI incentives.

This scenario is analyzed further using the Bayesian updating framework.

Migration and Investments – Bayesian Updating

Suppose that the prior belief of the entrepreneur in the advanced country concerning the fraction of the population of the lagging country without the cultural distance is defined by the binary distribution with two possible states of the world: $\theta \in \{\theta_L, \theta_H\}$ in which the fraction of adaptable workers is believed to be either low (θ_L) or high (θ_H). Moreover, firms have a prior belief (denoted by μ) that the current state of the world is θ_H (consequently the prior probability that the state of the world is θ_L equals $1 - \mu$)

An entrepreneur in the frontier country learns that there are $mp_{new}L$ perfect matches between immigrants' skills and local physical capital. Following Bayes' rule, the entrepreneur assesses the degree of cultural appropriateness of human capital abroad based on the prior beliefs, and the information signal $s_t = (mp_{new}L, mL)$ that includes the observed fraction of adaptable migrants ($p_{new}mL$), and the volume of immigrants that entered the frontier country (mL).

The likelihood that this sample has been drawn in the θ_H state of the world is given by:

$$(2.30) \quad P(\theta = \theta_H | mp_{new}L, mL) = \frac{P(mp_{new}L | \theta_H) \mu}{P(mp_{new}L | \theta_H) \mu + P(mp_{new}L | \theta_L) [1 - \mu]}$$

where

$$(2.31) \quad P(mp_{new}L|\theta_H) = \binom{mL}{mp_{new}L} \theta_H^{mp_{new}L} (1 - \theta_H)^{Lm(1-p_{new})}$$

$$(2.32) \quad P(mp_{new}L|\theta_L) = \binom{mL}{mp_{new}L} \theta_L^{mp_{new}L} (1 - \theta_L)^{Lm(1-p_{new})}$$

Hence

$$(2.33) \quad P(\theta = \theta_H | mp_{new}L, mL) = \frac{\theta_H^{mp_{new}L} (1 - \theta_H)^{Lm(1-p_{new})} \mu}{\theta_H^{mp_{new}L} (1 - \theta_H)^{Lm(1-p_{new})} \mu + \theta_L^{mp_{new}L} (1 - \theta_L)^{Lm(1-p_{new})} [1 - \mu]}$$

Based on their prior beliefs as well as based on the observed fraction of adaptable migrants ($p_{new}mL$) and the volume of immigrants that entered the frontier country (mL) investors form their expectations about the likelihoods of drawing a given fraction of culturally adaptable agents in the lagging country (denoted by p_{upd}) for a given level of employment in firms of type 3 (l_3):

$$(2.34) \quad P(l_3 p_{upd} | l_3) = \binom{l_3}{l_3 p_{upd}} (\Theta_L + \Theta_H)$$

where $\Theta_L \equiv \theta_L^{l_3 p_{upd}} (1 - \theta_L)^{l_3(1-p_{upd})} [1 - P(\theta = \theta_H | I)]$, $\Theta_H \equiv \theta_H^{l_3 p_{upd}} (1 - \theta_H)^{l_3(1-p_{upd})} P(\theta = \theta_H | I)$ and where $P(\theta = \theta_H | I)$ is given by (2.33).

To find the measure of the beliefs of entrepreneurs from the advanced country about the adaptability of human capital in the lagging country given by (2.20), we derive $E[\Lambda_{upd}^{1-\sigma} | I]$ (where $\Lambda_{upd} \equiv p_{upd} + (1 - p_{upd})\lambda$):

$$(2.35) \quad E[\Lambda_{upd}^{1-\sigma} | I] = \sum_{l_3 p_{upd}=0}^{l_3} P(l_3 p_{upd} | l_3) [p_{upd} + (1 - p_{upd})\lambda]^{1-\sigma}$$

From (2.35) we observe that entrepreneurs in the frontier country take into consideration not only the value of the observed average effective human capital in the (p_{new}) but also its volume (mL) and the expected value of employment in type 3 firms (l_3). Similarly to the general case of basic adjustment of beliefs, also in the case of Bayesian updating, a higher value of the observed cultural adaptability results in an upward-update of entrepreneurs beliefs about this value in the total foreign population ($\partial E(p_{upd})/\partial p_{new} > 0$).¹¹ However, using Bayes' rule the entrepreneurs take also into account the volume of migrants that entered the advanced country; the larger number of immigrants the stronger is the adjustment of entrepreneurs beliefs. Moreover, they also take into account the expected volume of employment in type 3 firms in the lagging country on (l_3); larger employment in type 3 firms reduces the variance of Λ and hence imposes more certainty with respect to the expected cultural adaptability.

To analyze how the application of Bayes' rule could affect the transmission mechanism between migration and formation of incentives we focus on the productivity of foreign investment. Recall that this expected productivity depends on the expected degree of cultural adaptability of foreign human capital ($E(p_{upd})$). Under the application of Bayes' rule, $E(p_{upd})$ is a function of the volume of migrants (m) according to (2.33), (2.18) and (2.35), hence the expected profitability of FDI will depend on the size of brain drain as well. This happens, because the expected productivity of a foreign investment depends on entrepreneurs perception of the degree of cultural adaptability of foreign human capital. When entrepreneurs perform Bayesian updating, this adaptability depends on the volume of immigrants.

Before we present the results of the simulation exercise, we introduce one simplifying assumption. We suppose that the employment in the type 3 firms will be large enough,

¹¹Note that: $E(p_{upd}) = \theta_H P(\theta = \theta_H) + \theta_L [1 - P(\theta = \theta_H)]$

so that entrepreneurs will not take into account its impact on variance of the expected cultural adaptability. Now we turn to the issue how Bayesian updating modifies the effects of migration on formation of investment incentives. First, we check how various values of immigration shares (m) affect the expected nominal productivity of foreign human capital, which in our model is represented by the parameter Ω as defined by (2.20). From (2.35) and from the fact that l_3 is large, Ω can be expressed as:

(2.36)

$$\Omega|_{l_3 \gg 0} = [P(\theta = \theta_H|I)[\theta_H(1 - \lambda) + \lambda]^{1-\sigma} + (1 - P(\theta = \theta_H|I))[\theta_L(1 - \lambda) + \lambda]^{1-\sigma}]^{\frac{1}{1-\sigma}}.$$

The immigration does not only affect the firms' incentives to invest in the lagging country by changing their beliefs about the human capital in the lagging country, but also by shrinking the pool of workers in the lagging country and increasing the pool of workers in the advanced country. Given the complexity of this issue, we decide to analyze it in a simulation exercise. In this exercise consider two scenarios that correspond to the cases of a different performance of migrants in the production in the frontier country, *cæteris paribus*.

In both scenarios the cultural distance is relatively large ($\lambda = 0.1$), the ex-ante expected degrees of cultural adaptability are equal to 0.8 (for θ_H) and 0.2 (for θ_L), and both states are believed to be equally probable ($\mu = 0.5$). In the first scenario migrants performance in production implies a relatively high adaptability ($p_{new} = 0.8$), whereas the second scenario refers to the case of a more moderate cultural adaptability of migrants ($p_{new} = 0.6$).

To study the total net effect of migration on investments, recall that it is a result of two effects. The first one refers to the updated perception of foreign degree of cultural adaptability, and hence a stronger investment incentives. The second one is related to

the fact, that more immigrants reduce the stock of foreign human capital available in the lagging country, which discourages entrepreneurs from the frontier country from investing in the lagging country. Hence, the net effect of migration on FDI will depend on the total effect of these two mechanisms. Figure 2.6 presents this net effect using the two analyzed scenarios as an example.

As shown in Figure 2.3 the number of investors (n) is initially increasing in the number of immigrants (m). This increase is due to a positive signalling effect, according to which the immigration increases investors' expectations about the value of the human capital in the lagging country. After the initial increase, the number of investors starts decreasing in the number of immigrants. This is because the effect of decreasing stock of labor in the lagging country starts to dominate the signalling effect.

The two scenarios differ with respect to values of $n(m)$. While $n(m)$ is always negative in the second scenario (dashed line), it has positive values for certain values of m in the first scenario (solid line). Hence, under the first scenario, for certain values of m , higher performance of migrants than expected triggers the investments. In the second scenario, even though the increasing number of migrants initially raises the expected profits from foreign investment, this is not enough to generate investment.

To reiterate, it should be kept in mind that the effect of migration on investment incentives will be weaker under Bayesian updating than in the case of simple adjustments of entrepreneur beliefs. This is because in this case the strength of the signal also depends on the volume of migrants. This implies that the informative signal that grows with the size of migration will be balanced with the shrinking stock of human capital. In other words, more migrants entering the advanced country imply on the one hand the clearer and stronger

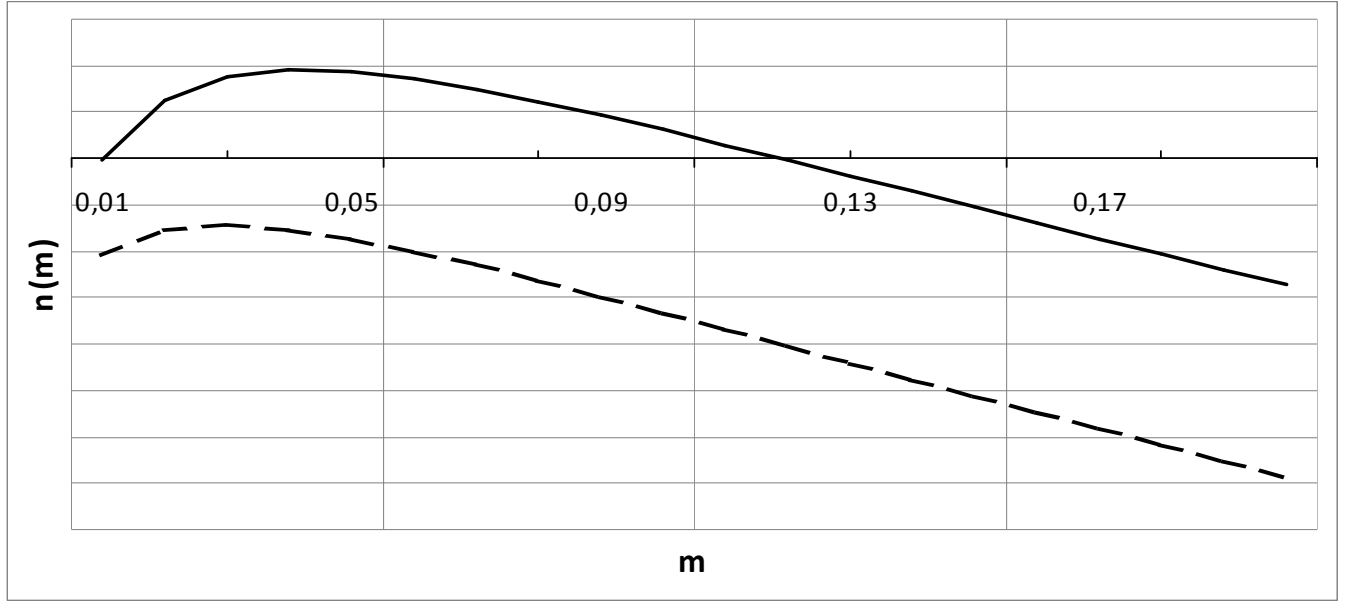


Figure 2.6. The effects of migration (m) on the investments ($n(m)$), for the following parameter values: $\theta_H = 0.8$, $\theta_L = 0.2$, $\mu = 0.5$, $\lambda = 0.1$, $\sigma = 0.66$, $L = 100$, $N = 50$ and $\tilde{A} = 3$.

signal to the entrepreneurs (and hence stronger migration incentives) but on the other hand shrinking stock of human capital abroad and thus weaker investment incentives.

2.3.3. Cross-Country Income Differences.

This subsection presents the origins of cross-country income differences. We start with a brief description of the concept of technological progress. Country-specific technologies (A_1 and A_2) are the element of production function that change over time in our setting.

Technological progress occurs as an externality in the process of production. At the end of each period, the aggregated technology employed in production in given country becomes public knowledge. Such technology is then used as production input in the next period.

Similarly to Barro and Sala-i-Martin (1997), the progress of technology is easier, when a given country lags far behind the technological frontier. The ease of the process of technological progress also depends on the stock of intellectual assets in given country and other

policy variables as intellectual property rights or taxation (see Barro and Sala-i-Martin, 1997; Barro, 2000 and Howitt, 2000 for further discussion). For simplicity, in this study, the rate of technological progress is assumed to depend only on the distance to the frontier and on the stock of human capital employed in given country. Particularly for the lagging country:

$$A_{2,t+1} = A_{2,t} [1 + \xi (A_{1,t}/A_{2,t}) H_{2,t}]$$

where $\xi > 0$ represents the productivity of intellectual assets in creation and adoption of new technologies and $H_i = Lh_i$ ($i \in (1, 2)$) is the total volume of human capital in a given country.

The rate of growth of productivity in the frontier country is therefore:

$$(2.37) \quad \left(\frac{A_{1,t+1} - A_{1,t}}{A_{1,t}} \right) = g_1 = \xi H_1,$$

and in the non-frontier country 2:

$$(2.38) \quad \frac{A_{2,t+1} - A_{2t}}{A_{2t}} = g_2 = \xi H_{2,t} \tilde{A}_t$$

Recall that \tilde{A}_t is the distance to the technological frontier, given by:

$$\tilde{A}_t \equiv \frac{A_{1,t}}{A_{2,t}} > 1$$

Given the initial distance to the technological frontier, and the rate of growth of productivity in the frontier country (g_1) as given by (2.37), the convergence process of the lagging country 2 is presented in Figure 2.7.

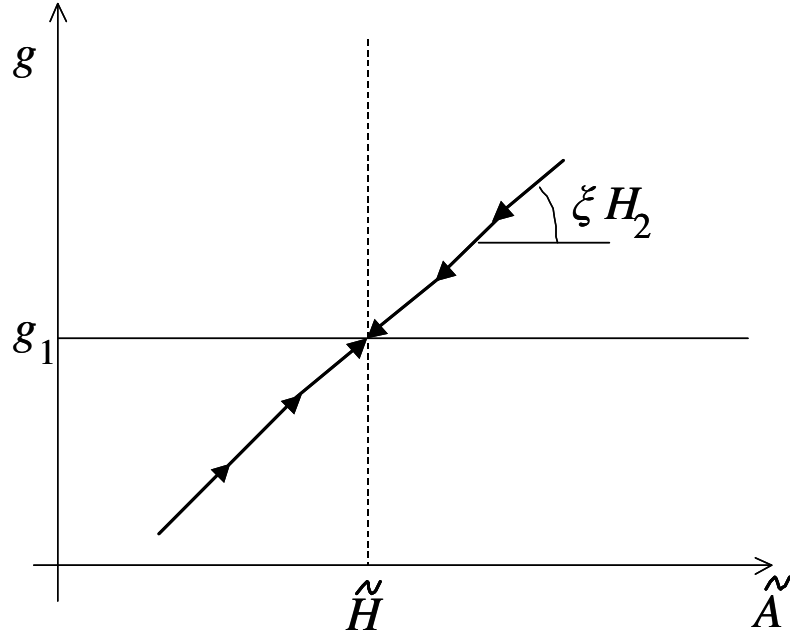


Figure 2.7. Convergence of growth of the lagging country.

If the technological gap is initially large, the lagging country grows temporarily faster than the frontier and converges to the steady-state, in which all economies grow at the same rate.¹² Analogously, when the initial distance is small the lagging country grows slower than the frontier country until it reaches the steady-state. In the steady-state the distance to technological frontier of a given lagging country is given by the differences in stocks of human capital:

$$\tilde{A} = \tilde{H}.$$

Now let us turn to the issue of cross country income differences.¹³ Clearly, when no investment flows and migration are allowed, the frontier and the lagging country differ with respect to their output, $Y_2 \leq Y_1$. In such a case, both economies grow at the same rate and

¹²Hence $g_1 = g_2$.

¹³Formally, suppose that $H_2 \leq H_1$ and $K_2 \leq K_1$.

the steady-state distance to frontier is described by:

$$\begin{aligned}
 \tilde{Y} &\equiv \frac{Y_1}{Y_2}, \\
 \tilde{Y} &= \tilde{A}\tilde{K}^\sigma\tilde{H}^{1-\sigma}, \\
 (2.39) \quad \tilde{Y} &= \tilde{K}^\sigma\tilde{H}^{2-\sigma}.
 \end{aligned}$$

Hence, without any way of contacts other than technological transfer, countries' long run positions depend only on their input factor endowments. The endowment of human capital plays a relatively more important role because it is used not only as a direct input in production, but also as an externality in the process of technological creation.

2.3.3.1. Brain Drain and Technological Progress. In the last part of this section we study the relationship between brain drain and technological progress (g_m), in both countries. To do this exercise we assume that the performance of migrants and production and the resulting cultural adaptability are perceived by the entrepreneurs in the advanced country to be representative for the adaptability of the whole population in the lagging country.

We check first for the effects of brain drain on the rate of technological progress of the advanced country. Suppose that the share of m^* migrants enters the advanced country. The entry of m^*H_2 immigrants from the lagging country to the frontier country implies the following rate of technological growth:

$$(2.40) \quad g_1 = \zeta (H_1 + m^*\Lambda H_2)$$

This is clearly larger than the rate of technological growth without the influx of skilled workers (2.37).

Now we check the effects of brain drain on technological progress of the lagging country. After the investment occurs, the technology in the lagging country improves then as an externality in the process of production in firms of type 2 and type 3. The growth of technology in the lagging country will differ from the case when no-investments took place and can be disintegrated into two components: (i) technological progress as an externality in production in type 2 firms; and (ii) the technological progress through spillovers of more productive technology employed by type 3 firms operating next door. Both components rely on local human capital (H_2). At the end of the second period, the aggregated technology employed in production in N firms of type 2 and $n(m^*)N$ firms of type 3 becomes public knowledge, i.e.:

$$A_{2,t+1} = \frac{1}{1 + n(m^*)} \left[\underbrace{A_{2,t}(1 + \zeta \tilde{A}_t H_{2,t}(1 - m^*))}_{\text{type 2 firms}} + n(m^*) \underbrace{A_{1,t}(1 + \zeta H_{2,t}(1 - m^*))}_{\text{type 3 firms}} \right]$$

Put it differently, at the end of the second period the average technology developed in firms active in the lagging country becomes public knowledge. The average also reflects the spillover effect, when firms of type 2 observe more productive firms of type 1 operating next door.

To determine the rate of growth of technological progress, recall that this is expressed by $g_2 = (A_{2,t+1} - A_{2t})/A_{2t}$. Hence:

$$\begin{aligned} g_2 &= \frac{(1 + \zeta \tilde{A}_t H_{2,t}(1 - m^*)) + n(m^*) \tilde{A}_t (1 + \zeta H_{2,t}(1 - m^*))}{1 + n(m^*)} - 1, \\ g_2 &= \frac{\zeta \tilde{A}_t H_{2,t}(1 - m^*)(1 + n(m^*)) + n(m^*)(\tilde{A}_t - 1)}{1 + n(m^*)}. \end{aligned}$$

In appendix B we show that the rate of growth of the lagging country shrinks in m . This means that after the initial, discrete increase of the growth due to migration-caused foreign investments, the growth rate tends to decrease in the rate of emigrating human capital. This is because of two reasons. First, growing brain drain implies smaller incoming foreign direct investments, which is one of the components of technological growth of the lagging country. Second, smaller human capital implies smaller local innovation capacities, and hence lower growth rate.

Notice that the rate of growth, that would be achieved without brain-drain equals to: $g_2 = \zeta \tilde{A} H_2 = g_1$. Such rate of technological progress can be achieved by the rate of brain drain m' that satisfies:

$$\zeta \tilde{A}_t H_2 = \frac{\zeta \tilde{A}_t H_{2,t} (1 - m') (1 + n(m')) + n(m') (\tilde{A}_t - 1)}{1 + n(m')}$$

Hence for smaller volumes of migration, the rate of technological progress is higher than under the no-migration scenario. This is represented in the Figure 2.8. The horizontal axis determines the rate of brain - drain (m^*). The flat line g_1 stands for the benchmark scenario, without migration, when $g_2 = \zeta \tilde{A} H_2 = g_1$. the downward - sloping line G represents the growth rate when the brain - drain takes place. Initially, when a lagging country gains technologically advanced investment, the rate of growth is higher than under the no-migration scenario. When the outflow of migrants grows, the lagging country becomes less attractive for investors and its human capital stock becomes scarce, so that overall the growth rate shrinks.¹⁴

¹⁴Notice that these scenarios are caused only when the flows of migrants and capital are observed - i.e. only when there are incentives for migration and investments.

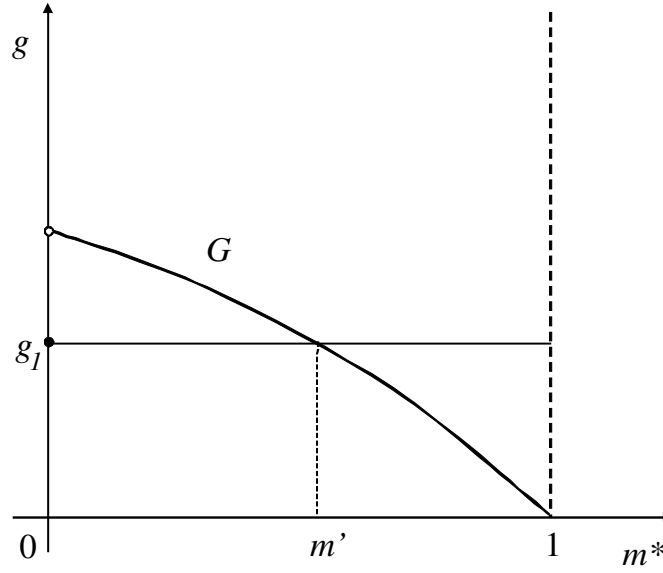


Figure 2.8. The effects of brain drain (m) on growth of the lagging country (g).

If m^* approaches one no investments follow the brain drain. In this case the effects on growth are only related to the loss of human capital and resulting smaller adoption capacities. Indeed since the new stock of human capital is $(1 - m^*)H_2 < H_2$ the growth rate is therefore $g(m^*) < g_1$.

Thus if brain drain works as an incentive for investment, a country can actually benefit from it in terms of faster technological adoption. However, once the rate of brain drain becomes large the negative effects tend to dominate and the total impact becomes negative. A proposition follows:

Proposition 2.2. *The brain drain has two opposite effects on technological progress of the lagging country: First, it has a negative impact through the reduction of the stock of human capital. Second, it has a positive effect through the direct technological transfer of investors from the advanced country.*

2.4. Policy Choices

This subsection analyses the possible policy prescription that can be drawn from the above presented theoretical analysis. In doing so we assume that cultural adaptability of immigrants is perceived to be representative for the whole population in the lagging country. For both countries we identify an area where policy implementation should be considered: immigration policy for the advanced country and investment subsidies for the lagging country.

2.4.1. *Advanced Country (Immigration Policy and Screening Mechanisms)*

A policymaker in the advanced country can apply two types of policy instruments. The first one is the immigration policy, which results in setting of the quota of migrants permitted to enter the advanced country (m). Second, the policymaker can introduce a screening mechanism designed to assess the degree of cultural adaptability of potential immigrants.

Immigration Policy

In order to present the formation of the frontier country's immigration policy, we check how brain drain might impact all parties potentially concerned as well as the general socio-economic effects in this country. In particular, we check how the brain drain could affect workers' wages, producers' profits and the rate of technological growth of the economy.

To study the effects of brain drain on profits and wages in the advanced country, recall the wage and profit equations as introduced by (2.3) and (2.6). In appendix C we show that $\partial\pi_1/\partial m > 0$ and $\partial w_1/\partial m < 0$. It implies that the effects of brain drain on firms in the frontier country are always positive and the effects on workers' wages – negative.

The effects of migration on firms are always positive – profits earned by the entrepreneurs rise as the quota of migrants grows. This is because human capital (including human capital

supplied by immigrants) is complementary to the firm-specific physical capital. Hence, more skilled immigrants generate in total higher output in the frontier country and more profits for the firm owners. In terms of the presented model, this can be seen in the profit equation (2.6) where incoming human capital increases the total volume of intellectual assets employed by a company and hence increases profits. This means that entrepreneurs of the advanced country are in favour of inflowing brain drain.

Other than entrepreneurs, native skilled workers in the frontier country do not need to benefit from brain drain. Taking into the accounts the immigrants, who due to the cultural barrier are on average less productive than the native workers, the individual wages in the frontier country fall. Hence, skilled workers in the frontier country (e.g. through the labor unions) will opt for reduction of immigration.

In addition to the effects on these two groups, brain drain has also some effects on growth. By equation (2.37) the growth rate of the advanced country depends on the total stock of human capital in this country. Since the total human capital without immigration (H_1) is lower than that with brain drain ($H_1 + E[\Lambda]m^*H_2$) the expected effects of brain drain on growth of the frontier country are clearly positive.¹⁵

To reiterate, the volume of migrants to enter the frontier country, denoted by m^* will be formed in the bargaining process between the labor unions and the entrepreneurs. The exact quota will depend on the balance of influence powers between entrepreneurs and workers. In addition, the social planner can also take into consideration the positive effects of brain drain on growth.

¹⁵The positive effects of brain drain on the destination economy have been empirically confirmed by numerous authors. See for example Borjas (1994, 1995).

Screening possibilities

In order to leverage the positive effects that brain drain has on the advanced country and to minimize its negative impact on local wages, the social planner might consider screening of immigrants that attempt to enter the advanced country. In particular, before entering the advanced country, each potential immigrant needs to go through a screening procedure to assess his or her potential to adapt to local working conditions (denoted by p_2). By designing such procedure a policymaker aims at letting only culturally adaptable agents to migrate to the advanced country, which in turn should strengthen the positive effects of brain drain.

In the terms of the model, this could be represented by a test performed at the moment of attempt of migration. An immigrant that according to the test will have a high degree of adaptability will be allowed to enter the advanced country. Consequently, a negative result of the test will imply a denial of migration, and the candidate will have to return to the lagging country.

The screening test is not perfect and it fails some agents with a high potential to adapt, as well as passes some agents that are not adaptable. Denote the accuracy of the test by $\gamma \in (0.5, 1)$, where $\gamma = 0.5$ denotes a completely random test that de facto does not distinguish between adaptable and not adaptable workers and $\gamma = 1$ refers to the case of an ideal test that perfectly distinguishes between adaptable and non-adaptable candidate immigrants.

Denote by p_a the probability of individual cultural appropriateness among the sample of individuals that attempt to immigrate. We assume that mL is sufficiently large to allow us to use the law of big numbers. Then the screening test will pass γp_a of adaptable candidates and $(1 - \gamma)(1 - p_a)$ of not adaptable ones. Hence, the share of adaptable agents in the final group of immigrants that will eventually enter the frontier country will be equal to Γ

(where $\Gamma \equiv \gamma p_a + (1 - \gamma)(1 - p_a)$). Consequently, the volume of immigrants that will enter the frontier country after the test equals to $mL\Gamma$ and is smaller than the initial volume of candidate migrants mL .

After the test certain agents have been banned from entering the frontier country. This group includes the agents with low potential of cultural adaptation that failed the test ($\gamma(1 - p_a)$) and those adaptable ones, who were erroneously classified as unadaptables $((1 - \gamma)p_a)$. These agents will return to the lagging country.

In the frontier country, new immigrants are employed by entrepreneurs. The fraction of adaptable agents in the set of immigrants (consequently denoted by p_{new}) equals to:

$$(2.41) \quad p_{new} = \frac{\gamma p_a}{\Gamma}$$

which is clearly higher than p_a for all values of γ larger than 0.5, i.e. for all cases when the test is not completely random. Consequently, the fraction of adaptable agents among those that have been rejected from entering the frontier country (denoted by $p_{rejected}$) equals to:

$$(2.42) \quad p_{rejected} = \frac{(1 - \gamma)p_a}{1 - \Gamma}$$

The entrepreneurs are aware of the imperfection of the test and know the rate of γ . Based on the observed performance of foreign human capital the entrepreneurs deduce the degree of appropriateness of foreign human in the group that initially attempted to migrate p_a . Consequently, the entrepreneurs will use then p_a to denote the expected value of cultural adaptability of foreign human capital, taking into account that some agents, with lower

adaptability have been rejected from entering the advanced country. Note that the volume of agents rejected from immigration equals to $mL(1 - \Gamma)$ and their degree of adaptability is $p_{rejected}$ as defined above. Hence, the remaining agents in the lagging country $((1 - m)L)$ have their adaptability to be equal to $p_{2,new}$ as described by:

$$p_{2,new} \equiv \frac{(1 - m)p_a + m(1 - \gamma)p_a}{(1 - m) + m(1 - \Gamma)}$$

Thus the labor market equation for the lagging country becomes:

$$(2.43) \quad nNl_3 + Nl_2 = (1 - m)(1 - \Gamma)L$$

and the corresponding equations for the frontier country are:

$$(2.44) \quad l_1 = \frac{L}{(1 - n)N}$$

$$(2.45) \quad l_1 = \frac{Lm\Gamma}{(1 - n)N}$$

To check if an introduction of such screening mechanism will modify the effects of migration on FDI incentives, we take into account the new labor market equations and we check the effects of such schemes on expected profitability of a foreign investment. Two effects need to be discussed here. First, higher adaptability of immigrants (p_{new}) implies that expected profits in the advanced country will rise as well (higher y_1). Second, since some agents will low adaptability will forced to return to the lagging country it means that that the new expected degree of cultural adaptability in the lagging country will be lower ($p_{2,new}$), which in turn will reduce the expected profits from FDI (lower y_3). Moreover both effects grow in the volume of candidate migrants (m).

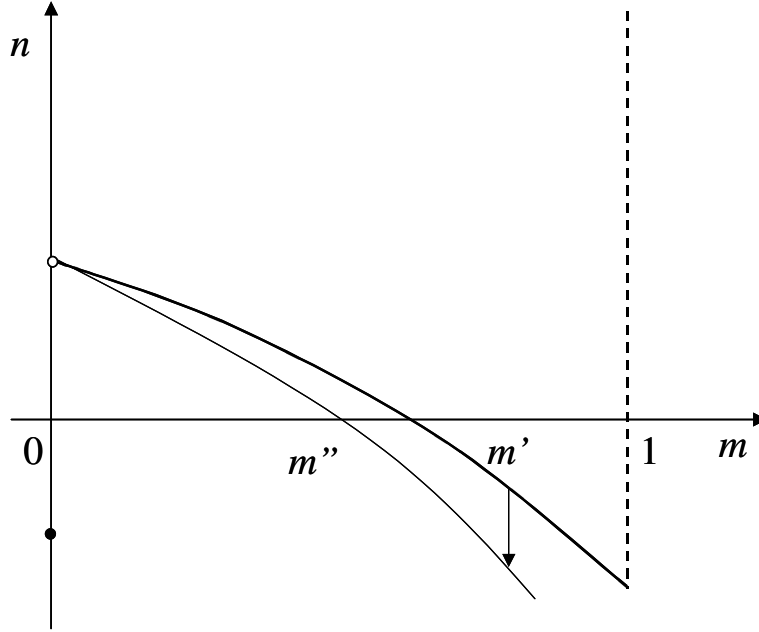


Figure 2.9. Screening mechanism and the effects of migration (m) on investments (n).

In sum, the total effect of a screening scheme on the relationship migration-investments is captured in the following equation, which is a modification of equation ($m(n)$):

$$(2.46) \quad n = \frac{1 - \left(\frac{\tilde{h} + m\Gamma\Lambda_1}{(1-m)(1-\Gamma)} \right) \left(\Omega_{2,new} \tilde{A}\tilde{k} \right)^{-1/\sigma}}{1 + \left(\frac{\tilde{h} + m\Gamma\Lambda_1}{(1-m)(1-\Gamma)} \right) \Omega_{2,new}}$$

where $\Omega_{2,new} \equiv [E(\Lambda_{2,new}^{1-\sigma})]^{1/(1-\sigma)}$ and $\Lambda_{2,new} = p_{2,new} + (1 - p_{2,new})\lambda$.

Figure 2.9 presents the impact that immigration tests will have on the effects that migration has on investments incentives.

Generally, introduction of an immigration test will weaken the incentives to FDI, due to the fact that the incoming workers have a higher degree of cultural adaptability than before and those agents that were returned to the lagging country reduce the foreign degree

of cultural appropriateness. Moreover, the larger the volume of immigrants the stronger the impact of screening on reduction of investment incentives. This is because of two reasons. First, more potential migrants imply that there are more non adaptable agents who failed the test and returned to the lagging country. Second, more migrants increase the stock of more adaptable agents that entered the advanced country, which increases local profits and discourages foreign investments.

2.4.2. Lagging country (*Subsidies to FDI*).

In the lagging country the policymaker might consider the use of FDI subsidies in order to attract foreign investors and to maximize the growth rate.¹⁶ This stands for the strategy in the process of development of direct import of technologies through attracting of foreign investors.

To determine the effects of subsidies on investment incentives, recall the equation that determines foreign profits (2.13). Taking into account the possibility of subsidies $(1 + \tau)$ leads to the following reformulation of the equation that describes the investor, who is indifferent between investing locally and abroad:

$$(2.47) \quad E[\pi_3] = (1 + \tau)\sigma A_1(k_1)^\sigma (l_3 h_2)^{1-\sigma} E[\Lambda_3^{1-\sigma}]$$

Since $\partial\pi_3/\partial\tau > 0$ this clearly means that higher FDI subsidies increase the expected return from capital investment. It means that FDI subsidies can potentially attract an

¹⁶For the purpose of tractability, suppose that the social planner in the lagging country aims at growth maximization. As the growth rate is the key element of welfare, we find this assumption plausible.

additional influx of foreign investments to the lagging country. Since the growth rate of the lagging country depends on the volume of incoming investments, it also implies that the subsidies to foreign direct investments can be considered as a tool for stimulating growth through technological transfer from abroad.

When designing the FDI subsidies strategy, a policymaker needs to keep in mind that such policy is the most effective when it leverages the possibly positive effects that brain drain has on investment incentives. In other words, a policymaker should target her FDI subsidies to countries where producers are close to be indifferent between investing at home and abroad, and where the subsidy is more likely to be effective. We illustrate this in the Figure 2.10, that outlines the investment incentives. The expected profits from foreign investments are presented on the horizontal axis, and the local profits are denoted on the vertical axis. The area below the 45-degree line corresponds to cases when a producer wants to invest abroad, whereas the area above this line presents cases when a local investment is more profitable for her.

An optimal application of FDI subsidies corresponds to the case A in the Figure 2.10.¹⁷ Profits that a producer from country A initially expected to generate correspond to point A1 in the Figure. An influx of foreign human capital resolved the producer's uncertainty about the appropriateness of foreign human capital, which corresponds to higher profits from foreign investments. Consequently, the investor's position moved to A2. However, this effect of brain drain was not sufficient to encourage the producer to invest abroad. An investment occurs after the application of FDI subsidies that would shift entrepreneurs position in the area where investments abroad become more profitable than at home (A3).

¹⁷Since the model assumed homogeneous producers in a country, for the purpose of this chapter we assume that each case corresponds to investors in a different country.

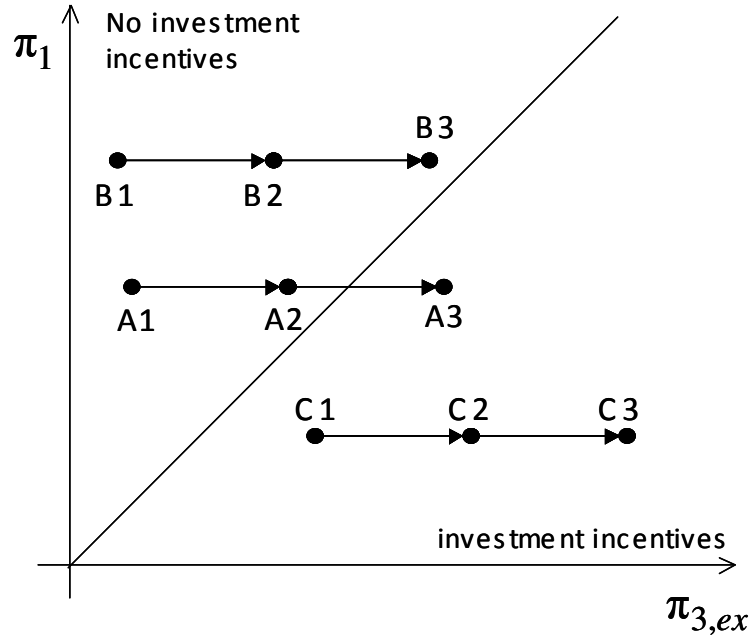


Figure 2.10. Profits from local and foreign investments

Contrary to the efficient use of FDI subsidies in the case of country A, the inefficient applications correspond to the stylized examples of countries B and C in the Figure 2.8. In the case of country B the differences between domestic and foreign profits are so significant, that the potential signal of cultural appropriateness and the subsidies to FDI cannot affect investors decisions. These high differences in profits mean that a potential subsidy instrument needs to be extremely attractive for the investors (and costly for the policymaker) to be effective.

A different scenario occurs in the case of country C. A producer from this country has been already convinced to invest abroad and a subsidy implied for her no change of plans. This implies that the application of the subsidy was in this case a net waste of public resources of the technologically lagging country, that a policymaker should avoid.

In sum, for the policymaker from the lagging country the FDI subsidies can be an effective tool to attract the foreign investments and trigger the transfer of foreign technologies.

The optimal design of subsidies schemes should include the information about the successful diaspora in a technologically advanced country. For a policymaker in a lagging country, a successful diaspora in the advanced country is a signal about of a potentially higher willingness of foreign producers to invest abroad, given their positive experience with foreign human capital. To further assess the potential effectiveness of the FDI subsidies, the policymaker should also take into consideration the comparison of different profits that a potential investor expects to earn in both countries.

This reinforces some of the recommendations made by the OECD (2003) toward attracting Foreign Direct Investment. According to these recommendations the policymakers could pursue targeting of FDI attracting strategies, which they could build on a particular advantage. In the context of this study, the presence of a skilled diaspora is clearly one of such advantages. The OECD also points that policymakers should be aware of a risk of a "wasteful" policy, where *"authorities find themselves subsidizing investment projects that would, with the benefit of hindsight, have taken place in the absence of incentives"*.

2.5. Brain Drain and Cultural Differences – Empirical Illustrations

One of the main implications of this chapter is that the brain drain triggers investments from the advanced country to the lagging country. In particular the following mechanism is postulated: Foreign direct investments are costly, and a notable share of these costs is due to cross country cultural differences. These differences result in a partial incompatibility between investor's know-how and foreign human capital and hence in lower final output. By employing foreign skilled immigrants in his/her home country the potential investor can verify the degree of cultural distance of skilled workers based on a sample of immigrants without bearing all the costs of cultural uncertainty related to FDI. Hence the brain drain

helps in resolving the uncertainty related to the cultural appropriateness of human capital and therefore can trigger the investments by lowering their costs to investors.

In this subsection, we present empirical studies that tend to support this mechanism. We also provide a suggestive empirical example, of the human capital and investment flows between the US and Canada.

2.5.1. Evidence in existing literature

The effects of skilled migration and diaspora externalities have only recently attracted attention of economist. Whereas most of the authors focus on the relationship between brain-drain and trade, few authors studied the effects of brain drain on investments flows. Although these studies do not present in depth the underlying mechanisms,¹⁸ they provide empirical examples that parallel our theoretical model.

Rauch and Trindade (2002), Rauch (2003) and Rauch and Casella (2003), recognized, that investments and migration could be complementary to each other as brain drain can reduce the transaction costs related to trade and investments. Although their analysis preliminary focused on trade flows and allocation of resources across countries, they also included analysis of the effects on migration. In particular Rauch (2003) included a case when skilled migrants have an effect on investments. Interestingly for the focus of this study one of the channels of transmission signalled by Rauch is the market information provided by migrants, who might be an excellent source of information to foreign investors with respect to their language and culture, habits etc.

¹⁸The potential causal mechanisms are often not explained in detail and are presented as a “black box”. In other cases only a short, intuitive background for the empirical observations is provided, such as that the trust created by the (skilled) migrants, additional market information provided by them and reduction of transaction costs.

Closer to the focus of this study, a set of sectoral and country examples was presented by several authors. Gao (2003) focused on the Chinese migrants abroad and found that significant share of FDI flowing to China originated in the Chinese diaspora. Similar conclusions were presented by Tong (2003), who analyzed the dependence of investment flows to China on the role of ethnic Chinese in a given country.

Buch, Kleiner and Toubal (2003) provided an example based on data on migration flows from and to Germany. They found migration to be correlated with the parallel flows of investments and performed an additional causality analysis. They concluded that migration from Germany has a casual effect on investments flows to Germany; whereas with respect to migration to Germany, the casual mechanism runs in the opposite direction.

In more recent studies Kugler and Rapoport (2005 and 2007) focused on the skilled migration to the US and the related FDI flows. They find that the negative relationship between current skilled migration and current FDI flows and strong relationship between past skilled migration and current investment flows as well as empirical confirmation for contemporaneous substitutability between migration and FDI.

Javorcik, et al. (2006) studied the link between the presence of migrants in the United States and U.S. FDI in the migrants' countries of origin. Their results suggest that the presents of migrants in the US (in particular migrants with a college education) is positively correlated with the US FDI in the migrants' home country.

Regarding sectoral studies, Saxenian (1999 and 2001) as well as Arora and Gambardella (2004) analyzed the case of employment and investments in the software industry and concluded that investment flows in this sector are (at least to some extent) driven by the influx of foreign skilled programmers.

Last, in their recent study Docquier and Lodigiani (2006) provide evidence for presence of diaspora externalities in empirical models of capital accumulation based on FDI. By using original data on capital and migration stocks they find evidence of strong diaspora effect that results in paralleled migration and investment flows.

2.5.2. Example: USA and Canada

This subsection provides an empirical example for causal effect that skilled migration might have on investment. We perform the analysis on the example of the United States and Canada. We take these two countries because of the availability of data on both US foreign direct investments in Canada, and the Canadian brain drain to the US. It will also allow us to avoid the problem of different measurement methods and potential heterogeneity of the sample. The data comes from Statistics Canada and the years of observations are 1982 to 1996 for the observations of the brain drain and 1989 to 2004 for the observations of FDI.¹⁹

During this period each year roughly 25,000 Canadians decided to migrate and settle in the United States. 8,000 to 10,000 of those are university graduates, and hence can be considered as a brain drain. In the analyzed period on average two thirds of total foreign direct investments to Canada were from the United States. US investments grew over that period from 13% of Canadian GDP in 1989 to 19% in 2004. Investments in the Canadian services sector amounted to average 10% of total FDI inflows.

To check whether there is any causality of migration of skilled agents from Canada to the US on American investments in Canada we performed Granger causality tests. The null

¹⁹Even though the introduction of NAFTA could be considered as an exogenous shock that could have significantly affect both migration and investment flows, this event had in fact no effect on US - Canada investment flows as reported by Blomström and Kokko (1997) and Burfisher et al. (2001).

hypothesis is in this case that the brain drain from Canada to the US does not cause FDI flows from the US to Canada.

The results of the tests are presented in Table 2.1. The first test considers the Canadian graduates who decided to settle in the United States. The null hypothesis is that a flow of such professionals does not cause an inflow of US FDI to Canada. The F -statistic from the test with a two-year lag is 3.804, which corresponds to a p -value of 0.122. The corresponding case with a three-year lag results in an F -statistic of 94.06 and p -value of 0.072. Thus, we reject the hypothesis that the brain drain from Canada to the U.S. does not cause FDI in the opposite direction.

The second step we perform is to check whether a causal effect can also be detected for FDI on the migration of skilled individuals. We wish to check whether U.S. investments could have any effect on Canadian skilled migration south. The F -statistic of the test is equal to 0.242 with a two-year lag (1.466 with a three-year lag) which corresponds to a p -value of 0.57 (resp. 0.504). Therefore, we cannot reject the null hypothesis that U.S. FDI in Canada does not cause a brain drain in the opposite direction.

Null hypothesis		$q = 2$	$q = 3$
Brain Drain \nrightarrow FDI	F -statistic	3.804	94.06
	p -value	0.122	0.072
FDI \nrightarrow Brain Drain	F -statistic	0.378	1.466
	p -value	0.57	0.504

Table 2.1.

The results of both tests are that the migration of Canadian graduates to the United States causes US investments in Canada. Therefore, one can conclude that in this case the brain drain seems to trigger investments from the migrants' destination country.

In terms of the general model, these results suggest that an update of *ex ante* beliefs on the appropriateness of foreign human capital indeed takes place, as the investors respond to the influx of skilled individuals.

2.6. Conclusion

This chapter shows that the brain drain may have some positive effects on the technologically lagging economies. Human capital that enters technologically advanced countries gives a signal to the local investors about the true quality of foreign human capital. If the signal is positive, producers tend to invest abroad and the technologically lagging country benefits not only from the capital transfer but also from transfer of advanced technologies.

However, as human capital is essential for the adoption of foreign technologies, the brain drain can cause a slowdown of the technological progress of the sending country. Moreover, the more human capital leaves a country, the less is this country attractive for foreign investors.

Thus, the total effect of the brain drain on the lagging country is ambiguous. Small volumes of brain drain can trigger capital flows, which result in direct transmission of technologies. Larger volumes of brain drain can cause a slowdown of the technological progress of the sending country.

Contrary to the developing countries, the brain drain phenomenon seems to have a generally positive impact on the performance of the developed ones. As the research technology

depends on positive externalities created by the stock of human capital, the brain drain increases the growth rate of technological progress. The empirical evidence about the beneficial effects that well educated immigrants have on developed countries supports the theoretical predictions. Moreover, firms in the technologically advanced country enjoy higher profits having employed foreign human capital. However, native workers in the technologically advanced can be worse off due to the brain drain as it has a negative impact on their wages. Thus, the immigration policy of the lagging country will be set in the process of negotiations between producers and workers, whereas the social planner can also take into account the beneficial long-term effects of brain drain on technological progress.

Regarding policy prescriptions for the lagging country, the above presented analysis together with existing evidence suggest that the key elements for economic performance are other factors related to the structure of the country rather than the brain drain itself. Those factors that prevent capital mobility, technological adoption and capital accumulation tend to be crucial in understanding the differences in income between countries. A possible policy prescription is therefore to create an environment which promotes the adoption of foreign solutions/technologies that improve local productivity instead of searching for alternative options. In addition, these solutions could optimally leverage the presence of the skilled diaspora in the technologically advanced countries.

Appendix

Appendix A

In this appendix we present the proof of proposition 2.1.

Suppose L large enough to let Ω_m converge to $p+(1-p)\lambda$ and suppose that $\Omega_0 < (\tilde{h}/\tilde{k})^\sigma/\tilde{A}$ and $p + (1 - p)\lambda > (\tilde{h}/\tilde{k})^\sigma/\tilde{A}$. Then, whenever there is no migration ($m = 0$), investors do not update their beliefs and Ω does not exceed (2.25). As a result, there are no investments in the lagging country ($n = 0$). When there is migration ($m > 0$), investors update their beliefs from Ω_0 to $\Omega_m = p_{new} + (1 - p_{new})\lambda$, where the second inequality follows from the convergence assumption. From (2.26) we find $n > 0$.

We now prove that $n'(m) < 0$. Recall that $n(m)$ as given by (2.26) equals to:

$$n(m) \equiv \frac{1 - \left(\frac{\tilde{h} + m\Lambda_1}{1 - m}\right) \left(\Omega_m \tilde{A} \tilde{k}^\sigma\right)^{-1/\sigma}}{1 + \left(\frac{\tilde{h} + m\Lambda_1}{1 - m}\right) \Omega_m}$$

The term $\left(\frac{\tilde{h} + m\Lambda_1}{1 - m}\right)$ grows continuously for m for $m \in (0, 1)$ hence the term n shrinks in m .

Appendix B

This appendix presents the effects of brain drain of the rate of technological progress of the lagging country.

Recall the rate of growth of the lagging country:

$$g_2 = \frac{(1 + \zeta \tilde{A}_t H_{2,t}) + n(m^*) \tilde{A}_t (1 + \zeta H_{2,t})}{1 + n(m^*)} - 1$$

First, notice that $\partial(\zeta \tilde{A}_t H_{2,t}(1 - m^*))/\partial m < 0$.

Second, differentiate g_2 with respect to n to get:

$$\frac{\partial g_2}{\partial n(m^*)} = \frac{\tilde{A}_t(1 + \zeta H_{2,t}) - (1 + \zeta \tilde{A}_t H_{2,t})}{(1 + n(m^*))^2} > 0$$

Given that $(1 + \zeta \tilde{A}_t H_{2,t}) < \tilde{A}_t(1 + \zeta H_{2,t})$ the term g_2 shrinks in m^* .

Since $\partial n/\partial m < 0$ (as shown in appendix A) and given that $\partial g_2/\partial n > 0$ and $\partial(\zeta \tilde{A}_t H_{2,t}(1 - m^*))/\partial m < 0$ the term g_2 shrinks in m^* .

Appendix C

This appendix checks the effects of brain drain on profits and wages in the advanced country. Recall the profit equation as introduced by (2.6) and wage equation as introduced by (2.3):

$$(2.48) \quad \pi_1 = \sigma A_1(k_1)^\sigma (h_1 l_1 + \Lambda_1 h_2 l_m)^{1-\sigma}$$

$$(2.49) \quad w_1 = A_{1,t}(k_1)^\sigma \Sigma_s p_s (1 - \sigma) (h_1 l_1 + \Lambda_s l_m h_2)^{-\sigma} h_1$$

Notice that since $\partial \pi_1 / \partial l_m > 0$ and $\partial w_1 / \partial l_m < 0$.

From the labor market equation for the migrants employed destination country (2.15), the share of per-firm employment of migrants in the advanced country (l_m) equals:

$$l_m = \frac{mL}{N(1 - n)}$$

Since $\partial l_m / \partial m > 0$ it is straightforward that $\partial \pi_1 / \partial m > 0$ and $\partial w_1 / \partial m < 0$.

CHAPTER 3

Intellectual Property Rights, Globalization and Growth

3.1. Introduction

One of the main concerns of the modern theory of economic development is how globalization affects economic performance. A significant recent aspect of globalization is the tremendous rise in the degree of economic openness and integration across the world. A key feature of this phenomenon is the increasing developing countries' share of world trade. Currently trade between the developed (OECD) and developing (non-OECD) countries is the fastest growing category in trade growth statistics (OECD, 2008). For example, over the past thirty years, the volume of U.S. trade (as a share of US GDP) with non-OECD economies has increased more than four-fold.

The issue of trade openness and the reduction of trade barriers is currently a matter of international debate. Until the mid nineties, developed countries had been the most active pursuers of trade liberalization, whereas now many amongst the less developed countries have begun to promote tariff reduction. The perception of beneficial effects of trade on growth seems to stand at odds with empirical findings, however. The tremendous growth in trade volumes contrasts with fairly stable growth rates that have been observed over the past 100 years in developed economies. A natural question to ask is whether the rising degree of trade openness has indeed had any effect on the growth rate of advanced countries, and whether we should expect it to. The present chapter analyzes the effects of changing trade policies on regional economic performance as well as on the world's growth rate.

A related issue addressed is the effect that the degree of protection of intellectual property rights (IPR) in developing countries has on regional and global economic performance. Many experts and commentators have argued that improvement in poor countries' intellectual property rights is key to obtaining growth enhancing effects (for example Li (2001) see Scotchmer (2004) for an overview). The importance of the issue of IPR was confirmed by its inclusion into the statutes of the WTO in 1994. However, after more than ten years, the extent to which less developed countries should protect intellectual property, and in whose interests such protection should be implemented, is still not clear.

From a theoretical point of view, there is no doubt that intellectual property rights matter. Most economists agree that technology is the engine of growth, and the key element that motivates people to devote resources to beneficial technology improvements is the potential to exploit rents from it, which the protection of intellectual property allows. Most authors agree that high standards of IPR protection are beneficial for the innovating economies (Dinopoulos and Segerstrom 2003; Gancia, 2003; Connolly and Valderrama, 2005). Some studies (e.g. Helpman, 1993) have, however, highlighted the negative aspects of IPR protection for lagging economies. Strong enforcement of intellectual property protection increases consumer prices and reduces trade benefits that could be crucial for developing economies. Most of these studies implicitly assumed perfect substitutability between internationally produced goods. Here we refer to famous hypothesis formulated by Armington (1969) and summarized by Krugman and Obstfeld (1994), that goods are differentiated according to region of origin. In other words, even within the same sector internationally produced goods are perceived by consumers as imperfect substitutes. Such formulation drifts the attention away from the international aspect of intellectual property rights and points at the local issues of IPR protection.

The term globalization mostly refers to an increase in international openness. In this study we analyze two different cases of openness: openness to international flows of ideas and openness to trade. In addition to the effects of trade policies, we consider the impact of regional intellectual property rights regimes on regional economic performance and the world's growth rate. Both issues previously highlighted in the literature play a role: IPR affects the incentives for research in the technologically advanced countries as well as prices paid by consumers. The present chapter seeks to understand to what extent improvements in local IPRs have an effect on the long-term growth rate and income levels in a globalized world. It also analyzes the role that trade tariffs play in the interaction with the long run rate of economic growth.

We develop a dynamic, general equilibrium model of growth and trade that, importantly, has no scale effects to analyze these issues. To do this, we merge two streams of the literature - modern endogenous growth theory (which allows sophisticated representation of an economy without scale effects) and North - South trade models. We use an extension of the Armington hypothesis to implement trade equations. Using a model without scale effects is essential here because the size of markets increases manyfold when countries open themselves to international trade. Models with scale effects, though simpler, lead to immediately counterfactual implications regarding growth rates, and are therefore of little use in analyzing growth related issues. The model developed here is a Schumpeterian multi-region model of growth with both horizontal and vertical expansions. One region (denoted the frontier country) is the technological leader and has highest aggregate quality of products. Firms from the frontier country devote resources to innovative R&D to discover higher quality products and firms from all other countries devote resources to R&D to innovate and to benefit from

spillovers from discoveries made by the technological leaders. A success in R&D in a non-frontier country results in quality upgrading of local products, which differ to some extent from their models in the frontier country. The costs of innovation in a given country depend on its distance to the technological frontier of the frontier country. The rates of innovation are endogenously determined based on expected profit maximization together with labor market clearing conditions.

The chapter relates closely to various streams of the literature. The first is the modern Schumpeterian growth literature pioneered by Grossman and Helpman (1991a), Aghion and Howitt (1992), Segerstrom, Anant and Dinopoulos (1990), and developed further by Young (1998), Howitt (1999) and Peretto and Smulders (2002). This stream of literature is concerned with the mechanics of economic growth. The recent contributions allow modelling economies growing at constant rates with factor inputs growing (hence - these models are consistent with empirical observations). The scale effect is neutralized in these models by markets expanding into new sectors which effectively dilutes research efforts pushing the frontier. The more populous a given economy, the greater the number of sectors (and thus potential directions of research) it comprises.

Although elegant and consistent with the data, such formulations cause problems when it comes to modelling trade. The question of what happens when two countries of different sizes (i.e. with a different number of sectors) start to trade still remains unaddressed in the studies that build on models without scale effects. Until now the literature that employed growth models without scale effects focused on the flow of ideas as the only means by which international interaction occurred. Here, we posit a modelling solution to the problem of trade between countries of different sizes and hence are able to analyze this situation as well. The key assumption which allows this is that the trade of goods from various

sectors facilitates horizontal expansion in smaller countries. This allows us to solve the model without introducing scale effects while at the same time not violating balanced trade accounting.

The chapter is also closely related to the literature on North - South trade.¹ We build on the existing North - South trade models (Grossman and Helpman 1991b, Taylor 1993 and 1994) with the addition of components that allow us to generate a model without scale effects. Some existing studies in this literature have solved the problem of scale effects by postulating the heterogeneity of countries with respect to R&D capabilities (Dinopoulos and Segerstrom, 2003). In contrast, we present a general framework in which there are no innate differences across agents in their capacity to perform R&D.

An additional question often analyzed in the growth literature concerns so called conditional convergence, see Barro and Sala-i-Martin (1997).² Conditional convergence seems to be confirmed by empirical studies (see Barro, 2001 for an overview) and assigns to each economy its destination position in the world's productivity rank. The position of a country in the world productivity rank is also called "distance to frontier", where the term frontier refers to the country with the highest productivity. Changes in policy might result in a shift in such destination distance to the frontier and lead to transitional growth. Numerous studies highlight factors that could affect conditional convergence and determine a country's distance to the frontier, such as capital productivity, rules of law, or distortions of domestic and international markets. Our study contributes by adding the degree of intellectual property rights protection as the additional factor that could affect conditional convergence.

¹See Krugman and Obstfeld (1994).

²*Conditional convergence* is a particular case of so-called β -convergence (Barro and Sala-I-Martin, 1995).

The quality of IPRs is often assumed to be captured by the R&D productivity parameter, which does not allow for a deeper analysis of potential disadvantages of strong IPR (Barro and Sala-i-Martin, 1997; Dinopoulos and Segerstrom, 2003). Other existing studies that analyze aspects of intellectual property protection mainly discuss their international aspects (Taylor 1993 and 1994, Gancia, 2003). A number of studies (e.g. Helpman 1993, Grossman and Lai, 2004) that consider local IPR regimes, focus on the potential drawbacks of strong IPR. Recent evidence on the costliness of imitation (Coe and Helpman, 1995 or Benhabib and Spiegel, 2002) suggests that one should include the costs of imitative R&D also. This could significantly change the conclusions by neutralizing the negative price effect through increased R&D incentives. Our study also develops this direction. Here, stronger IPR increases the price of locally produced goods, and also increases the expected returns from investment (which matters with positive costs of imitation).

The main results of the chapter are: (1) an improvement in IPR by lagging countries does not have any global effect on growth rates. (2) An improvement of intellectual property protection implies an deterioration of individual wages paid to labor relative to local profits. (3) The degree of IPR protection in a given economy affects its distance to the frontier.

This chapter is structured as follows. The next section sketches the theoretical model. Section 3 presents the dynamics of the model. Section 4 presents the main properties of the equilibrium and discusses the potential benefits of openness. Section 5 performs a simple empirical test that supports the theoretical predictions. The last section concludes and points out directions for future research.

3.2. The model

In this section we discuss the role of the main assumptions that underlie the theoretical model. We also present the basic equations we will use in our analysis. The construction of the model presented in this section heavily follows so called Schumpeterian models of creative destruction proposed by Grossman and Helpman (1991a) and Aghion and Howitt (1992). The formulation, which aims to rule out scale effects is heavily influenced by Howitt (1999 and 2000).

3.2.1. Overview

Consider a multi-region model where regions are distinguished by the size of population and by the degree of intellectual property rights (IPR) protection. Specifically, there is only one region - the frontier country - where intellectual property is fully protected.³ All other regions - the lagging countries - have weaker and thus imperfect protection of intellectual property.

Each region has a continuum of sectors that produce commodity goods. Each sector is subject to technical progress. Workers in all regions are assumed to be capable of conducting vertical (quality improving) R&D that improves the quality of a given good in an industry. Each industry offers an infinite number of potential technology improvements. Meanwhile there are new sectors created in the process of serendipitous discoveries. Newly created sectors start with technological levels similar to those already existing.

³Generally, the frontier country offers the highest level of IPR protection in the world. I assume that intellectual property is perfectly protected in the frontier country just for analytical convenience.

There are two channels of international interaction: trade in commodities and the flow of ideas. Incentives for trade come from individual preferences, as individuals gain additional utility from consumption of international products.

The second channel of international interaction is the flow of ideas. It affects both: vertical and horizontal expansion. First, the international flow of ideas allows for imitation of old technologies in the lagging countries. Imitation requires some resources to be spent. The costliness of imitation is an observed and widely accepted phenomenon, see, for example, Mansfield, Schwartz and Wagner (1981), Coe and Helpman (1995) or Benhabib and Spiegel (2002). Costliness implies that when a country wants to create a new generation of a product, it must pay costs proportional to the costs that have been paid to make the discovery and proportional to the current state-of-the-art technology in the given sector. This is captured by an *index of copying difficulty* that grows in each industry with cumulative R&D effort. This illustrates the case when firms choose among an infinite array of R&D projects with varying degrees of expected difficulty. In such a setting, projects with lower degrees of expected difficulty would be explored first, leaving the more difficult research projects to be explored later. Put it differently, in terms of vertical R&D - the further a sector in a given country is from the technological frontier, and the more steps "up the quality ladder" have been made abroad, the easier it is to take the next step. The second case of international flow of ideas concerns the pace of horizontal expansion (opening of new sectors). The new sectors are being created in the process of serendipitous discoveries. However, countries can benefit from goods trade of new sectors, so that they have the same numbers of sectors opened.

3.2.2. Industry structure

There is a continuum of regions indexed by j , that range from 0 to 1. In each region there is a continuum of industries indexed by $i \in [0, B_t)$, where B_t measures the total number of different industries in the region. In each industry i , firms differ with respect to the technology of production they possess. A better technology implies higher quality of a given good produced in industry i . To discover a better technology that leads to production of a higher quality product, firms in each industry participate in innovative R&D races. When the state-of-the-art technology in a given industry is ω , the next winner of an innovative R&D race becomes the sole producer with a $\omega + 1$ technology. Thus, over time, the qualities of good produced grow as innovations push technology in each industry up its “quality ladder”.

A more detailed description of the industry structure is presented later.

3.2.3. Individuals

Each region has a fixed number of households. Each household member lives forever and is endowed with one unit of labor that is inelastically supplied in exchange for a wage (w_{jt}). The number of members of each household grows exponentially at a fixed rate $g_L > 0$, the population growth rate. Each region has identical rates of population growth so that the ratios of population volumes in all regions are constant. Let $\bar{L}_j > 0$ be the size of representative household in region j at time $t = 0$ and let L_{jt} denote the supply of labor in region j at time t , hence:

$$(3.1) \quad L_{jt} = \bar{L}_j e^{g_L t}$$

Households in all countries share identical preferences. Each household is modeled as a dynasty that consists of infinitely-lived consumers that maximizes discounted lifetime utility given by:

$$(3.2) \quad U = \int_0^\infty e^{g_L t} e^{-\rho t} \ln u_t dt,$$

where $\ln u_t$ denotes the individual utility at t and ρ is the rate of time preference.

Individual utility at t is equal to:

$$(3.3) \quad \ln u_t = \int_0^{B_{jt}^{\max}} \left[\int_0^1 \ln \lambda^{\omega(j,i)} c_{jt}(i) dj \right] di,$$

where $c_{jt}(i)$ denotes the consumption of products from sector i in country j and B_{jt}^{\max} denotes the total number of sectors, of which goods are available in region j . The term $\lambda^{\omega(j,i)}$ is the quality of a given good i in a given region j with the convention that λ denotes the single improvement of a product's quality; $\omega(j,i)$ refers to the number of such improvements until now in sector i in country j .

Each individual at time t maximizes u_t subject to the budget constraint. The logarithmic preferences defined by (3.3) imply that in equilibrium each individual spends equal amounts per sector. Within each sector he demands goods produced in all countries.

Denote the consumption expenditures in country j by E_{jt} . The optimal consumption path requires

$$(3.4) \quad r_j = \rho - g_L + \frac{\dot{E}_j}{E_j},$$

where r_j is the nominal interest rate in a country j .

To express the gross prices that consumers need to pay for a given good, introduce the parameter $\tau_j \geq 1$. This parameter reflects the institutional, legal and regulatory impediments to entering directly into a market of country j by offering a consumption product. Parameter τ_j should be interpreted as iceberg cost of international trade.⁴

Denote by $p_{j't}(i)$ the world price of good i from country j' . Consequently, the price consumers in region j pay for good i from region j' equals to: $\tau_j p_{j't}(i)$. The demand for good i produced in country j' (denoted $c_{j't}(i)$) equals:

$$(3.5) \quad c_{j't}(i) = \frac{E_{jt}}{\tau_j B_t} \frac{1}{p_{j't}(i)}.$$

Consequently, the spending for good i produced in country j' ($c_{j't}(i)p_{j't}(i)$) is equal to:

$$(3.6) \quad c_{j't}(i)p_{j't}(i) = \frac{E_{jt}}{\tau_j B_t}.$$

Given that the value of spending on own goods is negligible for the total volume of spending, the total value of imports into a country j equals to the total value of the above expressed spending for good i produced in country j' across the countries and across the goods:

$$(3.7) \quad \int_0^{B_t} \int_0^1 c_{j't}(i)p_{j't}(i) dj' di = \frac{E_{jt}}{\tau_j}.$$

Concerning the value of exports, recall that the total world spending on a given good is equal to:

⁴We assume no discrimination in import tariffs.

$$(3.8) \quad \int_0^1 \frac{E_{j't}}{B_t \tau_{j'}} dj'.$$

Given that all countries produce all the goods, the value of exports will be equal to the sum of the above value for all the countries, i.e.:

$$(3.9) \quad \int_0^{B_t} \int_0^1 \frac{E_{j't}}{B_t \tau_{j'}} dj' di = \int_0^1 \frac{E_{j't}}{\tau_{j'}} dj'.$$

Balance on the trade account requires that for any country j the values of imports (3.7) and exports (3.9) are equal. Hence:

$$(3.10) \quad \underbrace{\int_0^1 \frac{E_{j't}}{\tau_{j'}} dj'}_{\text{exports}} = \underbrace{\frac{E_{jt}}{\tau_j}}_{\text{imports}}$$

3.2.4. Production and research

Production

Production consists of continuum of industries (indexed by i) using labor as the only input. One worker at time t can produce one good in industry i in country j of any quality not exceeding $\lambda^{\omega_t(j,i)}$. The highest quality level a worker can produce changes as a result of technological progress.

Every new discovery results in the establishment of a local monopolist that has the unique right to produce the product of the state-of-the-art quality in j . To determine Nash equilibrium prices, note that a local quality leader competes against local followers (displaced in the most recent step of creative destruction). The local followers possesses a technology

$\lambda^{\omega_t(j,i)-1}$. Thus with the Home follower potentially charging a price equal to the marginal cost of production (i.e. wage), the highest price that current quality leader can charge is the followers's price (w_{jt}) times the quality improvement (λ). Denote the instantaneous profits of a regional quality leader by $\Pi_{jt}(i)$, where:

$$(3.11) \quad \Pi_{jt}(i) = (\lambda - 1) \frac{p_{jt}(i)}{\lambda} \int_0^1 \frac{E_{j't}}{B_t p_{jt}(i) \tau_{j'}} dj'.$$

Substituting (3.10) and exports (3.11) we find that instantaneous profits at t of a regional monopolist in j are equal to:

$$(3.12) \quad \Pi_{jt}(i) = \frac{\lambda - 1}{\lambda} \frac{E_{jt}}{B_t \tau_j}$$

Note that the term above does not depend on i anymore. Hence, monopolistic profits in a given country are industry independent.

R&D

The R&D sector also uses labor as the only input. The purpose of research activity is to improve quality of the product in a given sector and obtain a rent on the improvement. However, in only one country (called frontier country) patents are protected perfectly, while patents in all the other countries (lagging countries) can be imperfect at protecting such rents. The imperfection of the strength of protection of intellectual property implies that at each instant of time there is a chance that the patent granted to the current monopolist becomes violable. Let σ be the instantaneous probability⁵ of such an event. In such a representation σ symbolizes both the degree of monopolistic power given to the discoverer and the quality of legal enforcement. The case of $\sigma = 0$ denotes the case when intellectual property rights

⁵Poisson arrival rate.

are perfectly protected, i.e. there is no risk for a current state-of-the art producer that his technology becomes publicly available. The opposite limiting case of $\sigma \rightarrow \infty$ means that there is virtually no protection of intellectual property in a given country.

If a company loses its patent before a succeeding discovery occurs, its sector becomes leveled to competition and Bertrand competition drives the prices to marginal costs of production $p_{jt}(i) = w_{jt}$.

Every vertical innovation in industry i increases product quality by an exogenous factor $\lambda > 1$. A successful discoverer benefits by a stream of monopolistic profits in their industry until replaced by the next discovery, or the patent becomes violable.

Labor is the only input in vertical R&D and free entry is assumed. Any R&D firm that hires $n_{jt}(i)$ units of labor in industry i at t is successful in discovery of the next higher quality product with instantaneous probability $[\phi n_{jt}(i)/x_{jt}]$ where ϕ is the productivity parameter of vertical innovations, and x_{jt} is the ease by which the next discovery step can be made. The difficulty by which the next step up the “quality ladder” is captured by the average gap in research effort between this country and the technologically advanced country. This captures the idea that as each country grows and x_{jt} increases over time, innovating becomes more difficult in each industry. Thus:

$$(3.13) \quad \frac{\dot{x}_{jt}}{x_{jt}} = \mu \left(\frac{\phi \frac{1}{B_t} \int_0^{B_t} n_j(i) di}{x_{jt}} - \frac{\phi \frac{1}{B_t} \int_0^{B_t} n_{1t}(i) di}{x_{1t}} \right)$$

where subscript 1 refers to the variables related to the frontier country and μ is a positive constant.

The free entry condition for the R&D sector implies that the marginal value of success in research ($\phi V_{jt}(i)/x_{jt}$) must equal marginal cost (wage). Hence:

$$(3.14) \quad \frac{\phi V_{jt}(i)}{x_{jt}} = w_{jt}$$

where $V_{jt}(i)$ is the value of expected returns from holding the stocks of regional quality leaders, defined in (3.15).

Furthermore, the value of expected returns from holding the stocks of regional quality leaders must equal the stream of profits discounted by the interest rate, rate of population growth and adjusted for the instantaneous probability of losing monopolistic power (captured by the probability of losing IPR protection, σ_j and probability of being displaced by another successful discovery $\phi n_{jt}(i)/x_{jt}$). Thus:

$$(3.15) \quad V_{jt}(i) = \int_t^\infty \Pi_{j\tau} \exp \left\{ - \left[\int_t^\tau (r_j + \phi n_{js}(i)/x_{js} + \sigma_j) ds \right] \right\} d\tau$$

Differentiating (3.15) with respect to time yields:

$$(3.16) \quad \frac{\Pi_{jt} + \dot{V}_{jt}(i)}{V_{jt}(i)} - \frac{n_{jt}(i)}{x_{jt}} \phi - \sigma_j = r_j$$

For an investor in a stock, every time increment brings profits of Π_{jt} and appreciation of stock value of \dot{V}_{jt} . In case of new discoveries or losses in IPR protection, the investor suffers a loss of V_{jt} . This happens if another firm reports a success in vertical R&D (with instantaneous probability $\phi n_{jt}(i)/x_{jt}$) or if a given sector becomes leveled (with instantaneous probability σ_j). The no arbitrage condition (3.16) implies that this return must equal the market interest rate r_j . Using (3.14) to eliminate $V_{jt}(i)$ in (3.16), we find an expression in which

only research intensity is sector-specific and all other variables are sector independent. It implies that sectors are symmetric and research intensity is the same across industries in a given country ($n_{jt}(i) = n_{jt}$ for all i).

Combining the above equation with (3.4), (3.12) and (3.16) yields:

$$(3.17) \quad \frac{\dot{\Theta}_{jt}}{\Theta_{jt}} = \frac{\lambda - 1}{\lambda} \Theta_{jt} \frac{\phi}{x_{jt}} + \frac{\dot{x}_{jt}}{x_{jt}} - \left[\frac{n_j}{x_{jt}} \phi + \sigma_j + \rho - g_L + \frac{\dot{B}_t}{B_t} + \frac{\dot{\tau}_j}{\tau_j} \right]$$

where the term Θ_{jt} denotes the ratio of per-sector expenditures (net of tariffs) and wages, such that: $\Theta_{jt} \equiv E_{jt}/(B_t \tau_j w_{jt})$.

Horizontal expansion

Horizontal expansion occurs in the process of serendipitous discoveries (as in Howitt, 2000). A successful event in the process of horizontal expansion results in establishment of a new industry lab in the manufacturing sector which initially enjoys a patent protection. New monopolists enjoy a profit stream until displaced by the next discovery. Assume that the technological level of the newly established industry is randomly drawn from technological levels of existing products. Each agent has the same propensity for discovery (ψ). Moreover, the trading countries benefit from the fact that they trade goods from various sectors, so that the volume of sectors in the globalized world is the same for all countries. The pace with which a new industry innovates is then determined by the largest country in terms of R&D capable population (L^{\max}).

Consequently, the rate of new product innovation is:

$$(3.18) \quad \dot{B}_t = \psi L_t^{\max},$$

where $\psi > 0$ and L_t^{\max} is the largest R&D capable population of a country engaged in globalization. Such representation is just a formal specification of the standard implicit assumption that trade creates consumer's awareness about the range of available varieties of products (e.g. Howitt, 2000; Dinopoulos and Segerstrom, 2003). In terms of technical specification of the model, this corresponds to the case when information on a new variety is instantaneously transmitted to all globalized countries.

Let $b_{jt} \equiv L_{jt}/B_t$ denote the volume of labor per sector in region j . Thus:

$$\begin{aligned} \dot{b}_{jt}/b_{jt} &= \left(\dot{L}_{jt}/L_{jt} \right) - \left(\dot{B}_t/B_t \right) \\ (3.19) \quad \dot{b}_{jt}/b_{jt} &= g_L - \psi[L_t^{\max}/L_{jt}]b_{jt} \end{aligned}$$

3.2.5. Labor market

Every agent in each region can choose between being employed in production or in a research company. Consequently, total population consists of people employed in production and R&D and the labor market equation for each country can be represented as follows:

$$\underbrace{M_{jt}}_{\text{production}} + \underbrace{B_t n_{jt}}_{\text{research}} = L_{jt}.$$

where M_{jt} is employment in manufacturing j at t . To find its value note that in a given country some sectors are levelled by competition and report Bertrand prices of $p_j(i) = w_{jt}$. Consequently, these sectors produce more and employ more workers than those where patents hold and prices are higher. Hence, in order to find the detailed amount of labor in production we need to introduce the term γ_{jt} that denotes the fraction of the total number of sectors in

j that report Bertrand prices (w_{jt}) whereas the remaining fraction of sectors $(1 - \gamma_j)$ reports monopolistic prices (λw_{jt}).

Thus for country j the employment in production equals to:

$$(3.20) \quad M_{jt} = \frac{E_{jt}}{B_t \tau_j} \left[(1 - \gamma_{jt}) \frac{1}{\lambda w_{jt}} + \gamma_{jt} \frac{1}{w_{jt}} \right]$$

Let $\Gamma_{jt} \equiv [(1 - \gamma_{jt}) \lambda^{-1} + \gamma_{jt}]^{-1}$, then:

$$(3.21) \quad M_{jt} = \frac{E_{jt}}{B_t w_{jt} \tau_j \Gamma_{jt}}$$

Hence for country j the labor market constraint becomes:

$$(3.22) \quad \frac{E_j}{\Gamma_j B_t w_{jt} \tau_j} + n_j = \frac{L_{jt}}{B_t}.$$

In general, the share of levelled sectors, γ_{jt} , changes over time, depending on the rate of creation of new sectors (\dot{B}_t as defined by (3.18)), research intensity in a country that results in establishment of a new IPR protected firm ($\phi n_{jt}/x_{jt}$), and IPR quality (σ_j). In particular the growth rate of levelled sectors (denoted by $B_{jt,leveled}$) will be equal to:

$$(3.23) \quad \frac{\dot{B}_{jt,leveled}}{B_{jt,leveled}} = \sigma \frac{B_{jt} - B_{jt,leveled}}{B_{jt,leveled}} - B_{jt,leveled} \phi n_{jt}/x_{jt}$$

so that, using $\gamma_{jt} \equiv B_{jt,leveled}/B_{jt}$ we may write

$$(3.24) \quad \dot{\gamma}_{jt} = \sigma_j - \gamma_{jt} (\sigma_j + \phi n_{jt}/x_{jt} + \psi b_{jt}).$$

3.3. The equilibrium

This section presents the solution of the model for a steady-state equilibrium. First, we present the solution for the frontier country and then for a lagging country j . We focus on the equilibrium allocation of resources between production and R&D. In terms of the model this corresponds to the variables n_j and E_j .

Four dynamic equations, together with one static equation describe the dynamics of a particular country. The endogenous variables are Θ_{jt} , x_{jt} , n_{jt} , b_{jt} and γ_{jt} . The dynamic equations are:

The stock market equation (3.17)

$$\frac{\dot{\Theta}_{jt}}{\Theta_{jt}} = \frac{\lambda - 1}{\lambda} \Theta_{jt} \frac{\phi}{x_{jt}} + \frac{\dot{x}_{jt}}{x_{jt}} - \left[\frac{n_{jt}}{x_{jt}} \phi + \sigma_j + \rho - g_L + \psi b_{jt} \right]$$

The horizontal expansion equation (3.19)

$$\dot{b}_{jt}/b_{jt} = g_L - \psi [L_t^{\max}/L_{jt}] b_{jt}$$

The equation that presents the evolution of the difficulty parameter (3.13)

$$\frac{\dot{x}_{jt}}{x_{jt}} = \mu \left(\frac{\phi n_{jt}}{x_{jt}} - \frac{\phi n_{1t}}{x_{1t}} \right)$$

The equation that represents the evolution of the industry structure (3.24)

$$\dot{\gamma}_{jt} = \sigma_j - \gamma_{jt} (\sigma_j + \phi n_{jt}/x_{jt} + \psi b_{jt}).$$

and the static equation is the labor market equilibrium (3.22) with the definitions of Θ_{jt} , Γ_{jt} , and b_{jt} substituted:

$$\Theta_{jt} [(1 - \gamma_{jt})/\lambda + \gamma_{jt}] + n_j = b_{jt}$$

3.3.1. Frontier Country

This section presents the solution of the model for the steady-state equilibrium in the frontier country. Since all sectors in the frontier country have monopolistic prices ($\gamma_1 = 0$ at any time t) and have maximal research difficulty ($x_1 = 1$ at any time t), solving the model reduces to solving a system of two equations [the innovative R&D condition given by (3.17) together with the horizontal market expansion (3.19)] in two unknowns [Θ_{1t} and b_{1t}] using the labor market equilibrium. In this respect, this model of trade is similar to Grossman and Helpman (1991a), who also obtain a system where the equilibrium is determined by the profit equation and resource constraint.

Solving the profit equation [(3.17) and (3.19)] together with the labor market constraint (3.22) yields the following steady-state conditions for the frontier country:

$$(3.25) \quad \frac{\dot{\Theta}_{1t}}{\Theta_{1t}} = \Theta_{1t}\phi - (\psi - \phi)b_{1t} + (\rho - g_L)$$

$$(3.26) \quad \frac{\dot{b}_{1t}}{b_{1t}} = g_L - \psi \frac{L^{\max}}{L_1} b_{1t}$$

In the long run, this system converges to the steady state where these two variables are equal to:

$$(3.27) \quad b_1 = \frac{g_L}{\psi} \frac{L^{\max}}{L_1}$$

$$(3.28) \quad \Theta_1 = \frac{\rho}{\phi} + b_1$$

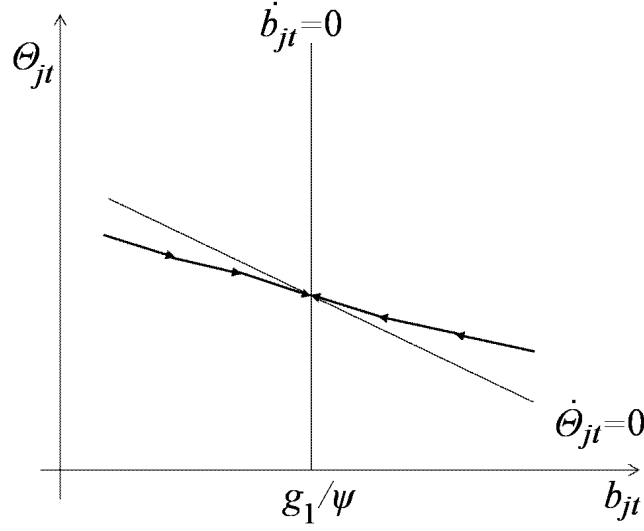


Figure 3.1. Convergence to the steady state in the frontier country.

Graphically this convergence is presented in Figure 3.1.

Plugging these values to the labor constraint (3.22) permits for representation of the R&D intensity in the frontier country:

$$(3.29) \quad n_1 = \frac{\lambda - 1}{\lambda} \frac{g_L}{\psi} - \frac{\rho}{\lambda \phi}$$

3.3.2. A lagging country

Before discussing the characteristics of this steady state, we briefly present the steady state in a lagging country j . Note that the values of expenditures and research of the frontier country (E_1 and n_1) are solved independently from values in the frontier country. They cannot be affected by any changes of policy in any lagging country. Hence, each lagging country takes the values of E_1 and n_1 as given.

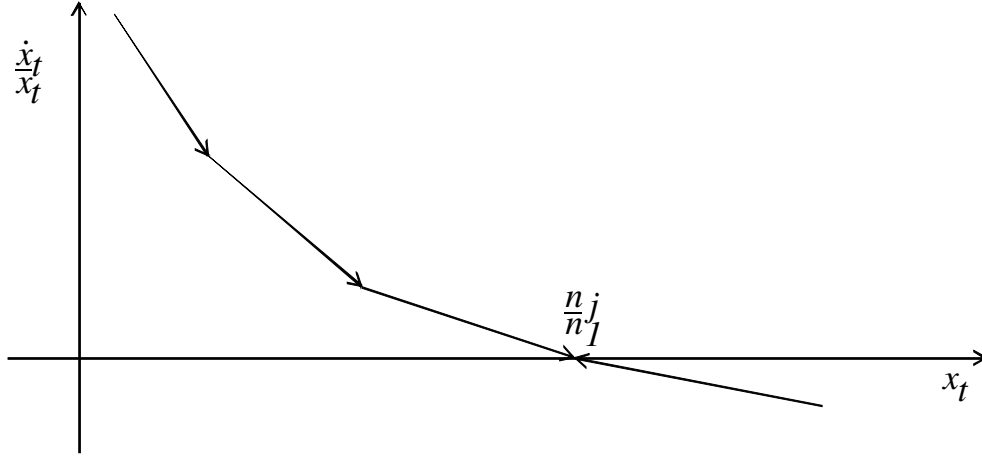


Figure 3.2. Convergence of research difficulty in a given country j .

To find the right expression for the vertical R&D intensity in j recall that difficulty becomes more difficult with technological progress, as expressed by (3.13).

$$(3.30) \quad \frac{\dot{x}_{jt}}{x_{jt}} = \mu \left(\frac{\phi \frac{1}{B_t} \int_0^{B_t} n_j(i) di}{x_{jt}} - \frac{\phi \frac{1}{B_t} \int_0^{B_t} n_{1t}(i) di}{x_{1t}} \right)$$

We assume that $x_{1t} = 1$ for all industries i which implies that when n_j and n_1 are constant the difficulty of innovation converges to a point where the differences in research intensity are balanced with a given difficulty. Graphically this is presented in Figure 3.2.

Hence in the steady state $\dot{x}_j = 0$ and the difficulty parameter has converged to:

$$\frac{n_j}{n_1} = x_j$$

Now we turn to the issue of distance to frontier, which here refers to the ratio of average product quality in country j to the average product quality in the frontier country. Denote with Ω_{jt} the average product quality in country j at time t such that:

$$\ln \Omega_{jt} \equiv \frac{1}{B_{jt}} \int_0^{B_{jt}} \ln \lambda_j(i) di$$

Using Leibnitz rule the time evolution of the average product quality in country j can be expressed as:

$$\ln \dot{\Omega}_{jt} \equiv -\frac{\ln \Omega_{jt}}{B_{jt}} \dot{B}_{jt} + \frac{1}{B_{jt}} \dot{B}_{jt} \ln \Omega_{jt} + \frac{\ln \Omega_{jt}}{B_{jt}} \left(\frac{\phi n_j}{x_j} B_{jt} \right) \ln \lambda$$

which yields the following growth rate of the average product quality in j :

$$\frac{\ln \dot{\Omega}_{jt}}{\ln \Omega_{jt}} \equiv \left(\frac{\phi n_j}{x_j} \right) \ln \lambda$$

This leads to an expression of growth rates of ratios of average product quality in a country j and in the frontier country:

$$\begin{aligned} \frac{\partial(\Omega_{jt}/\Omega_{1t})/\partial t}{(\Omega_{jt}/\Omega_{1t})} &= \left(\frac{\phi n_j}{x_j} - \frac{\phi n_1}{x_1} \right) \ln \lambda \\ \frac{\partial(\Omega_{jt}/\Omega_{1t})/\partial t}{(\Omega_{jt}/\Omega_{1t})} &= \frac{\ln \lambda}{\mu} \frac{\dot{x}_j}{x_j} \end{aligned}$$

which consequently leads to:

$$(\Omega_j/\Omega_1)^{\mu/\ln \lambda} = x_j.$$

Thus the difficulty parameter x_j is an iso-elastic function of the average quality offered by j 's firms relative to that in the frontier country. Therefore the inverse of the difficulty parameter $(1/x_j)$ can be used to denote the distance to frontier of an economy j .

Hence, in the steady state, vertical R&D intensity of a given lagging country is the frontier country's R&D intensity adjusted by the distance to the frontier:

$$(3.31) \quad n_j = x_j n_1$$

Constancy of γ_j together with (3.24) yields the following expression for j 's share of industries with Bertrand equilibrium:

$$(3.32) \quad \gamma_j = \frac{\sigma_j}{\sigma_j + \phi n_1 + g_L}$$

Rearranging equation (3.22) together (3.17) and together with the above expressions of j 's share of levelled sectors and vertical R&D intensity yields the lagging country's distance to frontier ($1/x_j$):

$$(3.33) \quad \frac{1}{x_j} = \frac{L_1}{L_j} + \frac{b_j}{\phi} \left[\gamma_j (\phi n_1 + \rho) + \left(\gamma_j + \frac{1}{\lambda - 1} \right) \sigma_j \right]$$

For a lagging country j the equilibrium is represented by four equations: (3.19), (3.31), (3.32) and (3.33), which solve for four variables: b_j , n_j , x_j and γ_j .

3.4. Main properties of the steady-state equilibrium

3.4.1. growth

We start the discussion of the above-described steady-state equilibrium from the perspective of the frontier country. The degree of IPR in any lagging country, and any foreign tariff do not appear in the frontier country's steady state conditions: (3.27) and (3.28). The volume of consumption expenditures (E_1) and research (n_1) in the frontier country do not depend on any foreign IPR regime or tariff policy. Hence, the frontier's (and the world's) growth rate are unaffected by any changes in tariffs or IPR regimes in the any of the lagging countries.

In summary:

Proposition 3.1. *In steady-state the rate of economic growth of all open economies is equal to the growth rate of the technologically most advanced economy. This rate of economic growth depends neither on any trade policies of any country (τ_j) nor on any potential changes in IPR regimes in technologically lagging countries (σ_j).*

Proof. In text □

In order to understand these results, recall the equations (3.10) and (3.12) assume the following intuitive mechanism of international trade that leads to a following re-interpretation of profits: each company in a given sector sells its product abroad to foreign companies in this sector at world prices (net of tariffs) and gets foreign products in exchange. These products are then sold locally and potential profits from these transactions are earned by local companies. Since consumers spend equal amounts on goods from each industry and each country, the profits of local producers (and here also importers) will be affected only by the value of local tariffs (see (3.12)).

Even though the values of local tariffs affect the volume of profits earned by firms, they will not affect the incentives to innovate. This is because the firms will simply adjust local wages, transferring the burden of higher tariffs onto workers (by lowering their wages). In terms of the model, this is represented by the constancy of Θ .

Thus, any changes of IPR policies in lagging countries, or of trade policy in any country, have no effect on expected profits from a successful discovery in the frontier country and hence are growth-neutral.

3.4.2. Distance to frontier

Now we restrict ourselves to study the effects of changes of IPR and tariffs on a given lagging country. The findings are summarized in the following proposition:

Proposition 3.2. *In a steady-state, a country's distance to technological frontier depends positively on the country specific inverse of protection of intellectual property rights (σ_j). Import tariffs (τ_j) are neutral in their effect on a country's distance to technological frontier.*

Proof. Recall the equation (3.33) that gives the unique solution for the distance to the frontier of a representative lagging country j .

Differentiating the distance to frontier ($1/x_j$) with respect to IPR term (σ_j) quality yields:

$$(3.34) \quad \frac{\partial(1/x_j)}{\partial\sigma_j} = \frac{L_1}{L_j} + \frac{b_j}{\phi} \left[(\phi n_1 + \rho + \sigma_j) \frac{\partial\gamma_j}{\partial\sigma_j} + \frac{1}{\lambda - 1} \right] > 0$$

which implies that a weaker IPR protection increases j 's distance to frontier.

Since the term of import tariffs (τ_j) does not appear in the country's expression of distance to technological frontier (3.33) it implies that import tariffs are neutral. \square

To reiterate, when patents in a given country are imperfect, then distance to the frontier increases with reductions in the quality of IPR protection. ($\partial(1/x_j)/\partial\sigma_j > 0$). Consequently, a discrete improvement of a country's IPR regime results in conditional convergence to a new position that is closer to the technological frontier. This is in contrast with the recent theories on IPR and development (Helpman 1993, Grossman and Lai, 2004). Taking into account the empirical finding about the costliness of the technological transfer changes the results - IPR are useful also for the lagging countries, as they guarantee some future profits that outweigh these costs..

Similarly, as in the frontier country, trade restrictions have no effect on conditional convergence of lagging countries. The underlying mechanism for this is the same as in the frontier country - any changes in tariffs result only in changes in trade volumes but not in expected rewards from monopolistic profits. A potential increase in tariffs in some regions causes a decrease in exports to these regions but it is only consumers in these regions, who suffer from these increases in tariffs. These results tend to suggest that, for a given lagging country, an improvement in the IPR regime seems to be a better solution than pursuing tariff changes.

3.4.3. Income Structure

To close this section we examine the potential consequences of IPR improvements on the income composition of a given lagging country. A commonly raised argument against stronger intellectual property protection is that it benefits only “capitalists” whose incomes come mostly as dividends from invested capital. According to such reasoning, workers whose incomes consist mostly of wages, do not benefit from these changes as much as "capitalists".

We study this claim by analyzing the effect of changes of σ_j on the composition of individual income. There are two main components of individual income: wages earned in production/research and dividends paid by monopolistic companies that produce consumption goods. From (3.12) and the definition of Θ_j we have:

$$(3.35) \quad \frac{\Pi_j}{w_j} = \frac{\lambda - 1}{\lambda} \Theta_j$$

Substituting the labor market equation (3.22) we find:

$$(3.36) \quad \frac{\Pi_j}{w_j} = \Gamma_j (b_j - n_j) \frac{\lambda - 1}{\lambda}$$

In the equation above there are two terms that depend on the inverse of IPR quality (σ_j): Γ_j and n_j . Note that Γ_j depends negatively on the fraction of sectors that report Bertrand prices, hence Γ_j shrinks in σ_j . Regarding the research intensity in country j notice that it can be expressed as $n_j = n_1 x_j$ (from (3.31)) and since by (3.34) $\partial(1/x_j)/\partial\sigma_j > 0$ it implies that $\partial n_j/\partial\sigma_j < 0$. Put it differently, there are two opposite channels of transmission from the inverse IPR quality (σ_j) to the profit - wage ratio. First, weaker IPR results in lower prices of consumption goods and higher relative wages. On the other hand, weaker IPR implies less R&D and through the crowding out-effect more supply of labor in production, which in turn results in lower wages. To check the net effect of IPR on the wage-profit ratio we perform a simulation exercise.

The exercise is performed for two different scenarios, with large and small population differences. In the first scenario $L_1/L_j = 5$ (black, dashed line in Figure 3.3) in the second scenario $L_1/L_j = 2$ (grey, solid line in Figure 3.3).⁶ As it can be seen in Figure 3.3 in a steady-state, the ratio of monopolistic profits and wage earned by workers depends negatively on the parameter σ_j (inverse of the IPR protection quality).⁷

Thus an improvement of the quality of IPR protection increase the profit/wage ratio. Weaker IPR implies that a larger share of income comes from wages paid to labor, whereas stronger IPR translates into higher significance of profits from successful R&D investments.

⁶The simulation exercise is performed for the following parameter values: $\lambda = 1.5$, $g_L = 0, 1$, $\rho = 0.05$, $\psi = 1.1$, $\phi = 1, 9$.

⁷In fact both lines are almost overlapping each other.

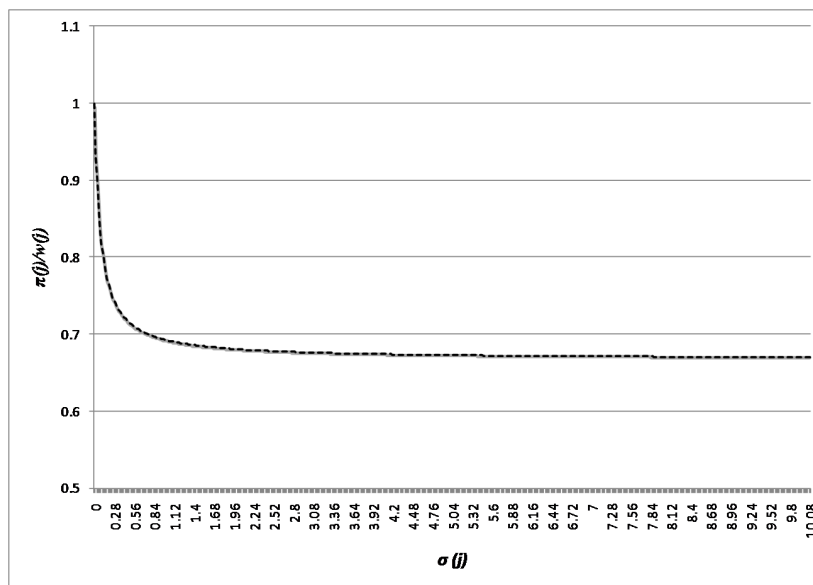


Figure 3.3. Effects of changes in the parameter σ on the ratio of monopolistic profits and wages.

If a country has an unequal distribution of equities, an improvement in IPR could indeed lead to a significant distortion away from labor, and increase inequality.

3.5. Empirical Studies on IPR, Growth and Income

There are some relevant empirical studies that examine the relationships between the quality of IPR regimes and growth and income levels. The quality of IPR protection has been quantified by a series of indices (Rapp and Rozek, 1990; Ginarte and Park, 1997; Ostergard 2000) which have been applied in macroeconomic analyses by various authors.

Concerning studies that focus on the dependence between IPR and the growth rate, it should be emphasized that the dependence between the quality of IPR and the per capita income concerns the long run equilibrium. Hence, in the short and medium term, when a given economy improves (or worsens) its IPR protection standards one could observe the temporary increase (reduction) of its growth rate. From this perspective of this study, an important work has been presented by Gould and Gruben (1996) who checked the relationship

between the short run rate of economic growth and the quality of local intellectual property rights regimes. Gould and Gruben studied the effects of patent protection on average yearly (hence short run) economic growth over 1960-1988. They found a significant positive effect of the strength of patent protection on economic growth – especially for open economies. Similarly, using average yearly growth of GDP over 1970-1985 for 112 countries, Rushing and Thompson (1996) found that stronger patent protection may contribute to short run economic growth. More recent empirical studies looked somehow deeper on the growth – IPR relationship. According to the Greenaway et al. (2006) strong patent protection appears to have a positive impact in the developing countries – presumably since such protection stimulates knowledge from the technologically advanced economies.

All these results are consistent with the results presented in this chapter. The quality of an IPR regime is a factor that determine the long run relative income of an economy, but has no effect on its long run growth rate. Thus an improvement of intellectual property rights protection in a given country should result in an improvement of the distance to frontier of this country, which would be paralleled with a temporary increase of the country's growth rate. Put it differently, an improvement of intellectual property rights protection should be expected to be correlated with higher short run transitional growth rates, which is confirmed by the above presented studies. Moreover, following the model, the transmission between the quality of IPR protection standards and short run growth should be relatively stronger for of open economies, which has been presented by Gould and Gruben.

There are indications that quality of intellectual property rights may affect the income level of an economy. Maskus and Penurbati (1995) used the Rapp and Rozek index of IPR quality to check its relationship with the income level of an economy. Since this index does

not take into account the degree of enforcement of intellectual property rights, Maskus and Penurbati used instrumental variables to solve this problem.

Following Maskus and Penurbati we check the relationship of IPR quality with the income level of an economy, but using a different index of IPR quality (IPR_{jt}). We refer to the IPR quality index introduced by Ostergard (2000). Unlike the index constructed by Rapp and Rozek and applied by Maskus and Penurbati, the index developed by Ostergard captures the degree to which intellectual property is literally protected with the quality of enforcement of given law, thus it captures the level of enforcement of intellectual property as well. Higher values of the index correspond to higher quality of IPR in a given country. The values of the index range from five (the best quality of IPR protection) to one (the worst quality of IPR protection). The second observable is the inverse distance to the frontier ($DIST_{jt}$), taken from Penn World Table on real GDP per capita relative to the United States.

Additionally, following with the theoretical results of the model, we wish to check the role of openness in the relationship between IPR and distance to frontier. To perform this exercise, the first step is to specify the subsets of open and closed economies. To do so it is not enough to look at the tariff rates or at the share of trade in GDP. In fact tariffs are just a nominal control variable and do not reflect many non - tariff barriers as well as whether a given economy is oriented to exchange with the globalized world or not. The share of trade in GDP is a highly endogenous variable and cannot be used as a credible proxy of openness. In order to determine the degree of openness of developing economies we take the index of openness introduced by Sachs and Warner (1995) where the “openness” of a given country depends on average level of tariff and non-tariff barriers, black market premia, central control of major exports, or whether a given country is classified as “socialist”. Following the theoretical predictions of Howitt (2000) and signalled by the empirical studies of Lichtenberg

(1993), we decide to control for the effects of investments on economic distance. We include the rate of investments as another control variable in the regression. We take the data from Penn World Table on the share of investments in GDP.

Our sample consists of 67 countries, both OECD and non-OECD economies.⁸ The sample consists of observations from 1988 and 1991.

Having defined the sub-samples that contain open and closed economies we perform the regressions with inverse distance to frontier (real GDP per capita relative to the United States) as the dependant variable. The estimated values of parameters for the open economies are presented in table two, the results for closed economies are presented in table 3.1. The intellectual property rights is highly significant for the distance to frontier of given country.

Notice that the exercise we will do checks the correlation between the index of IPR and relative income of a given economy. Given the shortage of the long - run data series, the question of the causation cannot be addressed so far.

Table 3.1: Open economies (83 observations, dependent variable $DIST_{it}$):

IPR _{jt}	17.535*** (1.894)	14.562*** (1.847)	14.457*** (1.855)	14.523*** (1.854)
Investments		1.198*** (0.276)	1.218*** (0.278)	1.180*** (0.278)
Openness			-0.054 (0.066)	
Time dummy				-2.859 (4.122)
R ²	0.513	0.606	0.609	0.608

⁸The economies classified as "open" in both periods: Australia, Austria, Barbados, Belgium, Bolivia, Canada, Chile, Colombia, Costa Rica, Denmark, Finland, France, Germany, Ghana, Greece, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Korea, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Thailand, United Kingdom, USA. Economies classified as "closed" in 1988 and as "open" in 1991: Argentina, Brazil, El Salvador, Guatemala, Hungary, Jamaica, Paraguay, Philippines, Poland, Tunisia, Turkey, Uruguay, Venezuela. Economies classified as closed in both periods: Bangladesh, China, Congo, Dominican Rep., Ecuador, Egypt, Haiti, Honduras, India, Kenya, Nicaragua, Nigeria, Pakistan, Panama, Peru, Romania, South Africa, Syria, Trinidad and Tobago.

Table 3.2: Closed economies (51 observations, dependent variable $DIST_{it}$):

IPR _{jt}	4.169*** (1.378)	3.979*** (1.346)	3.790*** (1.391)
Investments		0.514* (0.269)	0.491* (0.273)
Time dummy			-1.691 (2.791)
R ²	0.157	0.216	0.222

These correlations are not a test of the model, but it is encouraging that these are consistent with the theoretical predictions. Better protection of intellectual property tends to be correlated with the smaller distance to the frontier. A more in depth empirical analysis of this issue is a worthwhile subject of future research.

3.6. Conclusions

A central finding here is that the long-run growth rate is unaffected by either trade agreements or potential changes in IPR regimes in technologically lagging countries. This conclusion comes from the analysis of a standard multi-country model of trade and economic growth without scale effects. The conclusion is consistent with the empirical observations of no effect of factor input growth or increasing trade volumes on apparent long run economic growth rates in industrialized countries.

The second message that comes from this chapter is that because diffusion of technologies is not costless, differences in knowledge adoption intensities may explain a significant portion of income differences across countries. The main components that affect the cross - country differences in copying activities is the degree of intellectual property rights protection that significantly affects the long run relative productivity of a given country. Since the degree to which intellectual property is protected increases incentives to imitate, an improvement of IPR regime results in conditional convergence towards the technological frontier and to a

new steady-state equilibrium. This conclusion fits well the commonly known empirical observations on conditional convergence (see Barro, 2001). The results of two simple empirical regressions presented in section five additionally support these findings.

The last conclusion that needs to be highlighted regards the potential drawbacks of IPR improvement. Our model shows that better protection of intellectual property causes a shift in the distribution of individual income. A larger share of individual income comes from dividends paid by monopolistic firms. When there exists an unequal distribution of assets in a given society, this could lead to a significant distortion away from labour. Increasing inequality could trigger some undesired phenomena such as corruption and rent - seeking, that could even halt the development of a given region.

We finish this section with an indication of some points in the analysis that will be extended and improved in future research. We assumed throughout that each country was too small to affect world prices. This assumption will be relaxed in future studies. Doing so would allow one to check what happens if a single market matters for pricing decisions of firms or if a firm has enough market power to affect the prices in its sector. Finally, future research could focus on the identification of the other factors that affect international knowledge spillovers. Joint ventures, capital flows, migration of key personnel and cultural/geographical proximity may all play important roles.

References

- [1] Acemoglu, D., Aghion, P., and Zilibotti, F. (2006), "Distance to Frontier, Selection and Economic Growth", *Journal of the European Economic Association*, 4.
- [2] Aghion, P., and Howitt, P. (1992), "A Model of Growth through Creative Destruction", *Econometrica*, 60.
- [3] Armington, P. (1969), "A Theory of Demand for Products Distinguished by Place and Production", *IMF Staff Papers*, 16.
- [4] Arora, A. and A. Gambardella (2004), *The Globalization of the Software Industry: Perspectives and Opportunities for Developed and Developing Countries*; in A.B. Jaffe, J. Lerner and S. Stern, eds.: *Innovation Policy and the Economy*, Vol. 5, Cambridge, Ma.: The MIT Press.
- [5] Balland, J.-M., and Francois, P. (1996), "Innovation, Monopolies and the Poverty Trap", *Journal of Development Economics*, 49.
- [6] Barro, R. (2001), *"Determinants of Economic Growth"*, MIT Press, Cambridge, MA.
- [7] Barro, R. J. and Sala-i-Martin, X. (1995), *"Economic Growth"*, MIT Press
- [8] Barro, R. J. and Sala-i-Martin, X. (1997), "Technological Diffusion, Convergence, and Growth", *Journal of Economic Growth*, 2
- [9] Barro, R., and Sala-i-Martin, X. (2004): *Economic Growth*. MIT Press, Cambridge, MA, second edn.
- [10] Bartlett, C., and Ghoshal, S. (1989), *"Managing Across Borders: The Transactional Solution"*, Harvard Business School Press: Boston, MA.
- [11] Beine, M., F. Docquier, and Rapoport, H. (2004), "Brain Drain and LDC's Growth: Winners and Losers", mimeo.
- [12] Benhabib, J., and Spiegel, M. M. (1994), "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-country Data," *Journal of Monetary Economics*, 34(2), 143{174.
- [13] Benhabib, J., Spiegel, M. (2002), "Human Capital and Technology Diffusion", FRSBF Working Paper no. 2003-02.

- [14] Bhagwati, J. N., and Hamada, K. (1974), "The Brain Drain, International Integration of Professionals and Unemployment", *Journal of Development Economics*, 1.
- [15] Blomström, M. and Kokko, A. (1997) "How Foreign Investment Affects Host Countries", Policy Research Working Paper, no. 1745, World Bank.
- [16] Borjas, G. J. (1990), "Friends of Strangers: The Impact of Immigration on the US Economy", New York: Basic Books.
- [17] Borjas, G. J. (1994), "The Economics of Immigration" *Journal of Economic Literature*, 32.
- [18] Borjas, G.J. (1995), "The Economic Benefits from Immigration" *Journal of Economic Perspectives*, 9.
- [19] Borjas, G.J. (2005), "The Labor Market Impact of High Skill Immigration", *American Economic Review*, 95(2).
- [20] Buch, C.M., Kleinert, J., Lipponer, A. and F. Toubal (2005), Determinants and effects of foreign direct investment: evidence from German firm-level data, *Economic Policy*, January 2005: 51-110.
- [21] Burfisher, M., Robinson, S., and Thierfelder, K. (2001), "The Impact of NAFTA on the United States", *Journal of Economic Perspectives*, 15
- [22] Carrington, W. J. and Detragiache E. (1998), "How Big Is the Brain Drain?", IMF Working Paper, 98/102.
- [23] Coe, D., and Helpman, E. (1995), "International R&D Spillovers", *European Economic Review* 39..
- [24] Connolly, M., Valderrama, D. (2005), "Implications of Intellectual Property Rights for Dynamic Gains from Trade", *American Economic Review Papers and Proceedings* 95.
- [25] Cornell, B., and I. Welch. (1996), "Culture, Information and Screening Discrimination." *The Journal of Political Economy* 104(3)
- [26] Datta, D.K, P Herrmann, A.A Rasheed (2002), "Choice of foreign market entry modes: Critical review and future directions", *Advances in International Management*, 14
- [27] Di Maria, C. and P. Stryszowski (2009), "Migration, Human Capital Accumulation and Economic Development", *Journal of Development Economics*, 90 (2)
- [28] Dinopoulos, E., and Segerstrom, P. (1999), "A Schumpeterian Model of Protection and Relative Wages". *American Economic Review* 89.
- [29] Dinopoulos, E., and Segerstrom, P. (2003), "A Theory of North-South Trade and Globalization", CEPR Discussion Paper 4140.

- [30] Docquier, F. and E. Lodigiani (2006).. "Skilled Migration and Business Networks," Discussion Papers, Université catholique de Louvain, Departement des Sciences Economiques, 2006036
- [31] Docquier, F., O. Lohest, and Marfouk A. (2005), "Brain Drain in Developing Countries (1990-2000)", Discussion paper 1668, IZA.
- [32] Durlauf, S. N., and Johnson, P. A. (1995), "Multiple Regimes and Cross-Country Growth Behaviour", *Journal of Applied Econometrics*, 10.
- [33] Easterly, W. (2002), "The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics", MIT Press, Cambridge, MA.
- [34] Galor, O. and Tsiddon, D. (1997), "The Distribution of Human Capital and Economic Growth", *Journal of Economic Growth*, 2.
- [35] Gancia, G., (2003), "Globalization, Divergence and Stagnation", Stockholm University, Institute for International Economic Studies, Seminar Paper No. 720.
- [36] Gao, T.(2003), Ethnic Chinese Networks and International Investment: Evidence from Inward FDI in China, *Journal of Asian Economics*, 14
- [37] Ginarte, J. C. and W. G. Park. (1997), Intellectual property rights and economic growth. *Contemporary Economic Policy* 15(3).
- [38] Gould, D. M. and W.C. Gruben (1996), "The Role of Intellectual Property Rights in Economic Growth," *Journal of Economic Development*, 48 (2).
- [39] Grief, A. (1994), "Cultural Beliefs and the Organization of Society: A Historical and Theoretical Reflection on Collectivist and Individualist Societies", *Journal of Political Economy*, 102(5)
- [40] Grossman, G., and Helpman, E. (1991a), "Quality Ladders in the Theory of Growth", *Review of Economic Studies* 58 (1).
- [41] Grossman, G., and Helpman, E., (1991b) "Trade, Knowledge Spillovers and Growth", *European Economic Review* 35 (3).
- [42] Grossman, G., and Lai, E. (2002), "International Protection of Intellectual Property", *American Economic Review*, 94(3).
- [43] Guiso, L., Sapienza, P. and Zingales, L. (2004), "Cultural Biases in Economic Exchange", NBER Working Paper No 11005
- [44] Harzing, A.W.K. (2004), "Does language influence response styles? A test of the cultural accommodation hypothesis in fourteen countries, in: Setiadi," B.N.; Supratikny, A.; Lonner, W.J.; Poortinga, Y.H. *Ongoing Themes in Psychology and Culture*, International Association for Cross-Cultural Psychology (Selected and revised papers from the 16th IACCP congress).

- [45] Helpman, E., (1993), "Innovation, Imitation, and Intellectual Property Rights", *Econometrica*, 61
- [46] Heston, A., Summers, R., and Aten, B. (2002), *Penn World Table Version 6.1*, Center for International Comparisons at the University of Pennsylvania (CICUP).
- [47] Howitt, P. (1999), "Steady Endogenous Growth with Population and R&D Inputs Growing", *Journal of Political Economy*, 107 (4).
- [48] Howitt, P. (2000), "Endogenous Growth and Cross-Country Income Differences", *American Economic Review*, 90 (4).
- [49] Javorcik, B. S., C. Ozden, M. Spatareanu, and C. Neagu (2006), "Migrant Networks and Foreign Direct Investment", *World Bank Policy Research Working Paper* 4046, November 2006
- [50] Kalaitzidakis, P., T. P. Mamuneas, Savvides, A., and Stengos, T. (2001), "Measures of Human Capital and Non-Linearities in Economic Growth", *Journal of Economic Growth*, 6.
- [51] Kirkman, B.L, K.B. Lowe, and C.B. Gibson. (2006), "A quarter century of Culture's Consequences: A review of empirical research incorporating Hofstede's cultural value framework," *J. Internat. Bus. Stud.* 37
- [52] Krueger, A., and Lindahl, M., (2001), "Education for Growth: Why and For Whom?", *Journal of Economic Literature*, 39.
- [53] Krugman, P., and Obstfeld, M. (1994), *"International Economics: Theory and Policy"*, Addison Wesley.
- [54] Kugler M. and H. Rapoport (2005), *Skilled Emigration, Business Networks and Foreign Direct Investment*, *Cesifo Working Paper* No. 1455.
- [55] Kugler M. and H. Rapoport (2007) *International labor and capital flows: Complements or substitutes*, *Economic Letters* 94.
- [56] Kwok, V. and Leland, H. (1982), "An Economic Model of Brain Drain", *American Economic Review*, 72
- [57] Li, C.-W., (2001). On the polity implications of endogenous technological progress. *Economic Journal*, 111
- [58] Lichtenberg, F., (1993), "R&D Investment and International Productivity Differences", *NBER Working Paper* no. 4161.
- [59] Lowell, B. L. (2001) *Skilled temporary and permanent immigrants in the United States*, *Population Research and Policy Review*, 20(1-2).

- [60] Mansfield, E., Schwartz M., Wagner, S. (1981), "Imitation Costs and Patents: An Empirical Study", *The Economic Journal*, 91.
- [61] Maskus, K. E. and Penubarti, M. (1995), "How trade-related are intellectual property rights?" *Journal of International Economics*, Elsevier, 39(3-4).
- [62] Masters, a. (2004), "Firm level hiring policy with culturally biased testing," Discussion Papers 04-14, University at Albany, SUNY, Department of Economics
- [63] Mattoo, A., Olarreaga, M. and Saggi, K. (2004), "Mode of foreign entry, technology transfer, and FDI policy," *Journal of Development Economics* 75(1).
- [64] Meyerson, D. (1991), "Normal ambiguity? A glimpse of an occupational Culture", in Frost P. J. et al., *Reframing corporate culture*, Sage
- [65] Miyagiwa, K. (1991), "Scale Economies in Education and the Brain Drain Problem", *International Economic Review*, 32.
- [66] Mountford, A. (1997), "Can a Brain Drain be Good for Growth in the Source Economy?", *Journal of Development Economics*, 53 (2).
- [67] North, D. (1981), "Structure and Change in Economic History", Norton, New York.
- [68] OECD (2003), "Checklist for Foreign Direct Investment Incentive Policies", Organisation for Economic Co-operation and Development, Paris
- [69] OECD (2008a), "Intellectual Assets and Value Creation", Synthesis Report, OECD, Paris
- [70] OECD (2008b), *The Macroeconomic Policy Challenges of Continued Globalisation*, OECD Economic Studies No. 44
- [71] Ostergard, R. (2000), "The Measurement of Intellectual Property Rights Protection", *Journal of International Business Studies* 31.
- [72] Palich, L., and Gonzales - Meija, L. R., (1999), "A theory of global strategies and firm efficiencies: considering the effects of cultural diversity.", *Journal of Management*, 25.
- [73] Peretto, P., and Smulders, S. (2002), "Technological Distance, Growth and Scale Effects", *Economic Journal* 112 (481).
- [74] Rapp, R. and R. Rozek. (1990), "Benefits and Costs of Intellectual Property Protection in Developing Countries", *Journal of World Trade* 24
- [75] Rapp, R. T. and Rozek, R. P. (1990), "Benefits and Costs of Intellectual Property Protection in Developing Countries", *Journal of World Trade*, 24 (5).

- [76] Rauch J.E., and A. Castella (2006), "Overcoming Informational Barriers to International Resource Allocation: Prices and Ties" , *Economic Journal*, Vol. 113 (January 2003), pp. 21-42.
- [77] Rauch, J. (2003), *Diasporas and development: Theory, Evidence and Programmatic Implications*.
- [78] Rauch, J. E. and V. Trindade (2002), "Ethnic Chinese Networks In International Trade," *The Review of Economics and Statistics*, 84(1)
- [79] Rushing, F. W., and Thompson, M. A. (1996), "An Empirical Analysis of the Impact of Patent Protection on Economic Growth", *Journal of Economic Development*, 21 (2).
- [80] Sachs, J., and Warner, A. (1995), "Economic Reform and the Process of Global Integration", *Brookings Papers on Economic Activity*, Issue 1.
- [81] Saxenian, A. (1999), *Silicon Valley's New Immigrant Entrepreneurs*, Public Policy Institute of California, San Francisco, CA.
- [82] Saxenian, A. (2001) *Bangalore, the Silicon Valley of India?*, CREDPR.
- [83] Scotchmer, S., (2004). *Innovation and incentives*. Cambridge, Mass.: The MIT Press.
- [84] Segerstrom, P., (1991), "Innovation, Imitation and Economic Growth," *Journal of Political Economy*, 99(4).
- [85] Segerstrom, P., Anant, T. C. A., and Dinopoulos, E. (1990), "A Schumpeterian Model of the Product Life Cycle", *American Economic Review* 80.
- [86] Siegel, J.I., A. N. Licht, and S. H. Schwartz (2008), "Egalitarianism, Cultural Distance, and FDI: A New Approach", Available at SSRN: <http://ssrn.com/abstract=957306>
- [87] Spolaore, E. and Wacziarg R. (2006), "The Diffusion of development", CEPR discussion Paper 5630.
- [88] Stark, O., Helmenstein, C., and Prskawetz A. (1997), "A Brain Gain with a Brain Drain", *Economics Letters*, 55.
- [89] Stark, O., Helmenstein, C., and Prskawetz A. (1998), "Human Capital Formation, Human Capital Depletion, and Migration: a Blessing or a Curse?", *Economics Letters*, 60.
- [90] Taylor, M. (1993), "TRIPS, Trade, and Technology Transfer", *Canadian Journal of Economics* 26 (3).
- [91] Taylor, M. (1994), "TRIPs, Trade, and Growth", *International Economic Review* 35 (2).

- [92] Tihanyi, L., Griffith, D. A., and Russell C. J. (2005), "The effect of cultural distance on entry mode choice, international diversification and MNE performance: a meta - analysis", *Journal of International Business Studies*, 36.
- [93] Tong, S. (2003), *Ethnic Networks in FDI and the Impact of Institutional Development*, Working Paper, University of Hong Kong.
- [94] Vandenbussche, J., Aghion P., and Meghir, C. (2004), "Growth, Distance to Frontier and Composition of Human Capital," mimeo, Harvard University.
- [95] Vendrik, Maarten C.M. and C. Schwieren (2005), "Identification, screening and stereotyping in labor market discrimination," Research Memoranda 013, Maastricht : ME-TEOR, Maastricht Research School of Economics of Technology and Organization
- [96] Vidal, J.-P. (1998), "The Effect of Emigration on Human Capital Formation", *Journal of Population Economics*, 11(4).
- [97] World Bank (1993), *"The East Asian Miracle"*, Oxford University Press, New York.
- [98] World Bank (2001), *"Rethinking the East Asian Miracle"*, Oxford University Press, New York.
- [99] Young, A. (1998), "Growth Without Scale Effects", *Journal of Political Economy* 106 (1).

Samenvatting

Dit proefschrift richt zich op twee factoren die belangrijk zijn voor economische groei en het inkomen van een land. Deze factoren zijn:

- “Brain drain”: hieronder verstaan we de migratie van hoog opgeleide, getrainde en getalenteerde individuen,
- “Intellectuele eigendomsrechten”: hieronder verstaan we het juridisch bepaalde (overdraagbare) alleenrecht op het gebruik van verschillende soorten van scheppingen van de geest, zoals uitvindingen, namen, merken en modellen.

Om een beter inzicht in de rol van deze factoren in het proces van economische ontwikkeling te verkrijgen, construeren we theoretische modellen die we illustreren met empirisch materiaal. Hieronder geven we een korte schets van drie studies die de drie hoofdstukken van dit proefschrift vormen.

De eerste twee hoofdstukken analyseren de effecten van “brain drain” op de economische prestaties van een land. De migratie van hoogopgeleide personen wordt algemeen geacht een aanzienlijke invloed te hebben op de inkomensverschillen tussen landen. Borjas (1995) heeft laten zien dat empirisch de impact van de brain drain op de lange termijn gunstig is voor de economieën die de migranten ontvangen. De theoretische verklaring benadrukt menselijk kapitaal als belangrijkste ingrediënt in de productie van goederen of diensten en in “research and development” activiteiten, waardoor het land van bestemming voordelen heeft van de brain drain. Oudere theoretische studies als die van Bhagwati en Hamada (1974) en Kwok

en Leyland (1982) hebben gewezen op de negatieve effecten van de uitstroom van menselijk kapitaal op de economieën die hun migranten wegzenden. Dit theoretisch inzicht kan echter in strijd zijn met het feit dat relatief welvarende landen soms veel meer getalenteerde en geschoolde migranten uitzenden dan hun minder welvarende burens, zoals bijvoorbeeld Taiwan en Zuid-Korea in vergelijking met Bangladesh en Indonesië. Een ander opvallend voorbeeld is Nederland, dat ondanks een relatief hoog percentage van afgestudeerden die migreren naar de Verenigde Staten, nog steeds een van de rijkste economieën ter wereld is.

Brain-drain kan dus zowel positief als negatief verband houden met de welvaart in een land. In dit proefschrift willen we een mogelijke oorsprong duiden voor deze twee mogelijke verbanden. We doen dit door te wijzen op twee transmissie mechanismen, namelijk via investeringen in menselijk kapitaal (hoofdstuk 1) en via directe buitenlandse investeringen (hoofdstuk 2). We construeren theoretische modellen voor de analyse van deze transmissie mechanismen van braindrain op de economische prestaties van een land. Met een aantal empirische verkenningen ondersteunen we de theoretische analyse.

In het eerste hoofdstuk beargumenteren wij dat niet alle soorten menselijk kapitaal even geschikt zijn in een bepaald stadium van de ontwikkeling van een land. We veronderstellen dat de afstand tot de “technology frontier” een belangrijke determinant is van de geschiktheid van het menselijk kapitaal: hoe dichter economieën de grens van het technologisch kunnen zijn genaderd, hoe meer ze behoefte hebben aan een evenwichtige verdeling van de beroepsbevolking over verschillende technische vaardigheden, creativiteit, sociaal-wetenschappelijke competenties, juridische expertise en ondernemerschap. Echter, in eerdere stadia van economische ontwikkeling, wanneer het land nog ver is verwijderd van de technologische grens en wanneer het meest valt te verwachten van een inhaalbeweging door het

kopiëren van beschikbare technologieën, is er een relatief grotere behoefte aan specialisatie in meer technische vaardigheden.

In het model in dit hoofdstuk kiezen individuen ander soort onderwijs als ze weten dat ze mogelijk emigreren. We gaan na wat het gevolg is van dit verband tussen migratiemogelijkheden en onderwijskeuze voor de economische ontwikkeling van een bepaald land. We volgen het werk van Vandenbussche e.a. (2004) door te veronderstellen dat economieën van elkaar verschillen door hun afstand tot de technologische frontiers. Economische groei is afhankelijk van de hoeveelheid en de samenstelling van het menselijk kapitaal in het land. De optimale samenstelling hangt sterk af van de afstand van het land tot de technologische frontiers.

We laten zien in het model dat een land kan blijven steken op een persistent laag inkomensniveau (“development trap”) wanneer de mogelijkheid van migratie al in een vroeg stadium van de economische ontwikkeling wordt geboden. In het vooruitzicht van de migratie zullen personen uit het ontwikkelingsland namelijk besluiten te investeren in het soort menselijk kapitaal dat weliswaar gewenst is in het land dat migranten ontvangt, maar minder goed van pas komt in de economie die de migranten achterlaten. Als deze laatstgenoemde landen migratie niet (volledig) kunnen voorkomen en ongeschikte investeringen in menselijk kapitaal willen ontlopen, dan zullen ze het verwerven van technische vaardigheden meer moeten subsidiëren naarmate ze zich verder van de technologische grens bevinden.

We laten onze theoretische bevindingen volgen door een empirische illustratie met betrekking tot de Zuid-Oost-Aziatische landen, die hun onderwijsstelsel centraal hebben geregeld en zowel hoge groeipercentages als snelle convergentie hebben bereikt.

Het tweede hoofdstuk is ingegeven door een andere empirische waarneming met betrekking tot het fenomeen van de migratie, namelijk een waarneming die het verband met investeringsstromen betreft. Zoals blijkt uit tal van empirische studies (bijvoorbeeld de studie

van Blomström en Kokko, 1997), komt technologie overdracht tot stand als gevolg van een instroom van buitenlandse directe investeringen vanuit technologisch geavanceerde landen. In wat volgt stellen we dat de “brain drain” gunstig kan zijn voor de uitzendende landen omdat de “brain drain” kapitaalstromen uit het buitenland oproept. Het theoretische argument over het causale effect van de braindrain op kapitaalstromen wordt geïllustreerd door een empirisch voorbeeld. Gezien de beperkte beschikbaarheid van gegevens over de brain drain, richten we onze empirische analyse alleen op de VS - Canada relatie. De empirische analyse toont, in lijn met het theoretische argument, de positieve correlatie tussen de instroom van hoogopgeleide Canadese immigranten naar de VS en de buitenlandse directe investeringen van de VS in Canada. Bovendien vinden we, eveneens in lijn met de theorie, dat de richting van de causaliteit loopt van brain drain naar buitenlandse directe investeringen.

Het laatste hoofdstuk verlegt de aandacht van brain drain naar de effecten van de handel en intellectuele eigendomsrechten op groei- en inkomensniveau. Bescherming van intellectueel eigendom speelt een essentiële rol in de moderne groeitheorie, vooral binnen de zogenaamde (neo-)Schumpeteriaanse benadering, omdat het ondernemers in staat stelt winst te halen uit innovatie en zo de technologische vooruitgang in de markteconomie stimuleert die de motor achter de groei is. Het grootste deel van de literatuur baseert zich op de veronderstelling van de oneindig lang lopende patenten en octrooien. De veronderstellingen over de octrooi-regelingen in de meeste groeimodellen zijn nogal impliciet. Intellectuele eigendomsrechten worden verondersteld perfect uitvoerbaar te zijn en onbeperkt in looptijd, zodat het onmogelijk is ideeën te stelen, octrooien te omzeilen, of te laten aflopen. Deze veronderstelling wordt soms losgelaten - meestal door "diefstal" van ideeën via imitatie te modelleren (zie bijvoorbeeld Segerstrom, 1992), soms ook door het bewuste beleid van een kopiërend land te modelleren (Taylor, 1994). Omdat octrooien behoren tot de belangrijkste

fundamenten van de moderne groeitheorie, is het interessant om de effecten van internationale verschillen in regulering van intellectueel eigendom op de economische prestaties te onderzoeken.

In het derde hoofdstuk beargumenteren we dat niet alleen de veronderstelling van perfect uitvoerbare patenten losgelaten moet worden, maar evenzeer de in de neoklassieke groeitheorie vaak gemaakte veronderstelling dat nieuwe technologie onmiddellijke overgenomen kan worden zonder kosten. Empirisch onderzoek wijst uit dat de verspreiding van technologie juist tijd kost en alleen plaats vindt als de vele barrières overwonnen kunnen worden.

In ons laatste hoofdstuk bestuderen we de effecten van onvolledig octrooibeleid op economische ontwikkeling in het geval van niet-verwaarloosbare kosten van de verspreiding van nieuwe technologie. Onze bijdrage aan de literatuur is de ontwikkeling van een nieuw model dat niet alleen neo-Schumpeteriaans van karakter is, maar ook schaaleffecten op de groei uitsluit, en Noord-Zuid handel in beschouwing neemt. Onze resultaten geven aan dat een verscherping van intellectuele eigendomsregelingen een verbetering inhoudt van het lange termijn inkomensniveau van een land ten opzichte van zijn handelspartners, terwijl importtarieven hierop geen invloed hebben. Onze empirische verkenning ondersteunt deze bevinding.